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CSM/LM SPACECRAFT OPERATIONAL DATA BOOK

VOLUME IV

EMU DATA BOOK

REVISION 1

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MANNED SPACECRAFT CENTER
HOUSTON, TEXAS

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CSM/LM SPACECRAFT OPERATIONAL DATA BOOK

VOLUME IV

EMU DATA BOOK

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PREFACE

This document is the first revision issue of the EMU Data Book. This revision incorporates Amendments 1 through 22. Amendments released subsequent to the publication of this revision will be numbered sequentially with the next amendment number (i.e., 23 and on).

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1.0 INTRODUCTION

1.1 Purpose

This document presents performance information regarding the mission capabilities and limitations of the Extravehicular Mobility Unit (EMU). This information is intended for use in nominal mission planning and to provide the performance characteristics of the EMU during normal mission operations.

1.2 Content

The complete Data Book for manned missions will consist of five separate volumes, defines as follows:

Volume I - CSM Data Book - Part 1 Perfomrnace, Part 2 Launch Rules

Volume II - LM Data Book - Part 1 Performance, Part 2 Launch Rules

Volume III - Mass Properties Data Book

Volume IV - EMU Data Book

Volume V - ALSEP Data Book

This volume, Volume IV, is divided into four sections, plus an appendix for each individual mission which contains consumable data and performance information for each flight EMU. The volume presents the EMU system and subsystem performance data for Zero-G and lunar excursion missions. A brief discussion of the scope of the sections of Volume IV follows.

1.2.1 Section 1.0, Introduction

The introduction describes the purpose and scope of the overall data book, and summarizes the content of the remaining sections. It includes a list of abbreviations used in this volume.

1.2.2 Section 2.0, EMU Configuration

This section contains pictorial representations of the EMU and its subassemblies. These data are intended as reference material for use throughout the data book.

1.2.3 Section 3.0, EMU Constraints and Operational Limitations

The restrictions, limitations, and special recommendations on the use of the EMU and its subsystems are contained in this section.

1.2.4 Section 4.0, Subsystem Performance Data

This section presents data concerning subsystem performance so that the mission planner and monitor can be familiar with system capabilities and normal operating characteristics.

1.2.5 Appendices

An appendix is presented for each mission. Each appendix presents data applicable to specific flight EMU's. PIA data are entered in these appendices as it becomes available. The data presented also contains consumable information applicable to that mission.

1.3 Amendments

Amendments to this document will be made by page additions or replacements. Data changed by an amendment will be denoted by an amendment date and number in the upper right-hand corner of the page, and a vertical bar in the page margin to locate the change. The vertical bar will only be used, however, when the change is made to verbal descriptive material. A revision page identifying the accumulative changes that have been made will be issued with each amendment. This page should be placed just behind the title page, and will provide an up-to-date listing of all amendments.

1.4 Selected Abbreviations and Acronyms

C

CDR	Commander
CM	Command Module
CMP	Command Module Pilot
CSM	Command and Service Module
CWG	Constant Wear Garment

E

EKG	Electrocardiogram
EMU	Extravehicular Mobility Unit
EV	Extravehicular
EVA	Extravehicular Activity
EVCS	Extravehicular Communications System
EVT	Extravehicular Transfer

F

F/W	Feedwater

I

ITMG	Integrated Thermal Micrometeoroid Garment
IV	Intravehicular

L

LCG	Liquid Cooling Garment
LEVA	Lunar Extravehicular Visor Assembly
LiOH	Lithium Hydroxide
LM	Lunar Module
LMP	Lunar Module Pilot

M

MSC	Manned Spacecraft Center
MSFN	Manned Space Flight Network

N

NASA	National Aeronautics and Space Administration

O

OPS	Oxygen Purge System

P

PGA	Pressure Garment Assembly
PIA	Pre-Installation Acceptance
PLSS	Portable Life Support System

R

RCU	Remote Control Unit
RF	Radio Frequency

S

S/C	Spacecraft

T

TBD	To Be Determined
TM	Telemetry
T/W	Transport Water

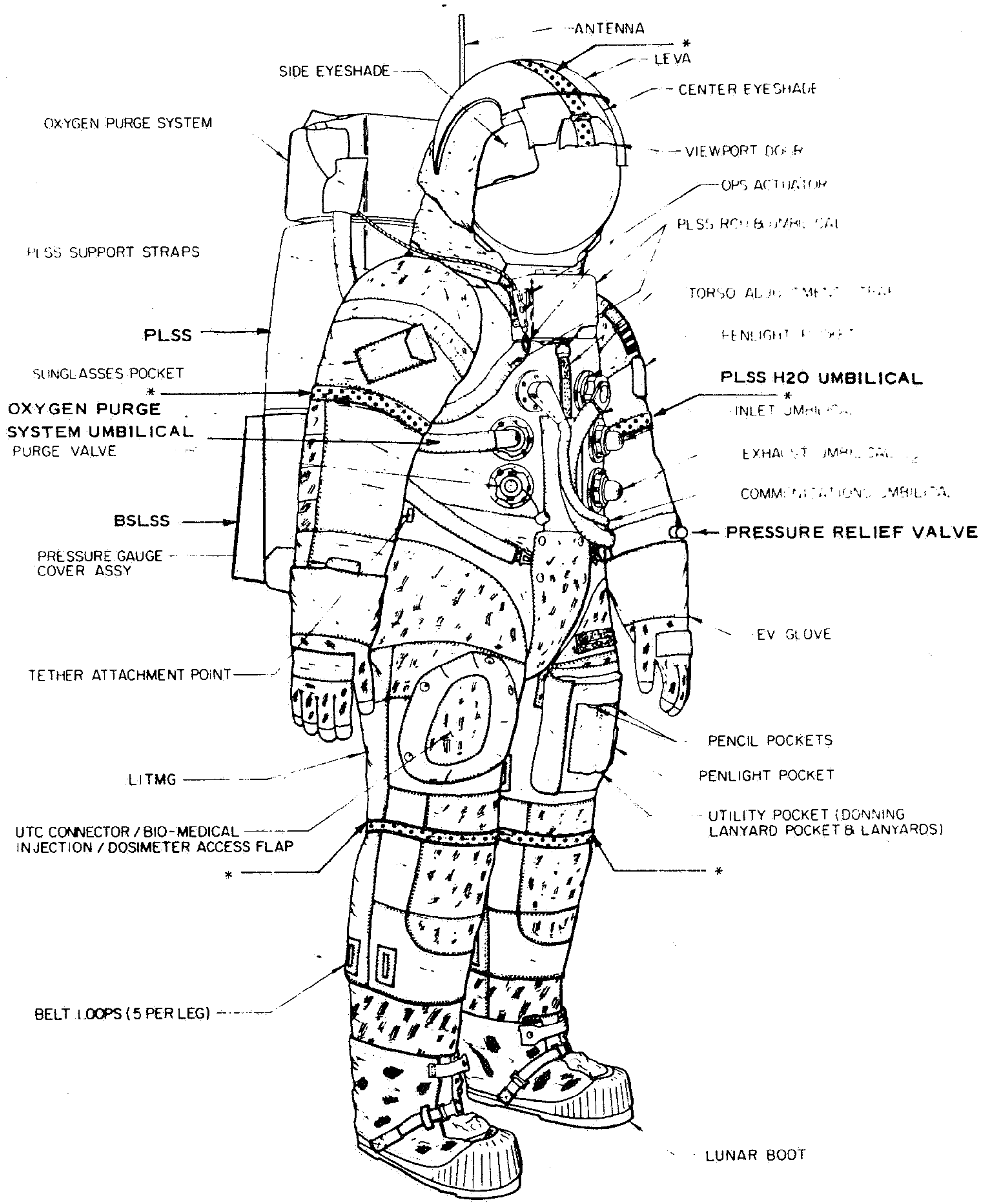
U

UCTA	Urine Collection and Transfer Assembly
UV	Ultraviolet

2.0 EXTRAVEHICULAR MOBILITY UNIT CONFIGURATION

2.1 Extravehicular Mobility Unit Configuration

Figures 2.1-1 and 2.1-2 show the EMU configuration. The function of the EMU is to provide the Apollo extravehicular crewman with a habitable environment with sufficient mobility to perform EVA tasks for a design EVA period of four hours. The system is capable of performing in free space or on the lunar surface. It can be replenished from LM supplies for performing three additional EVA missions.



* IDENTIFICATION STRIPES ON CDR EMU ONLY

Figure 2.1-1.- Extravehicular Mobility Unit (lunar surface configuration).

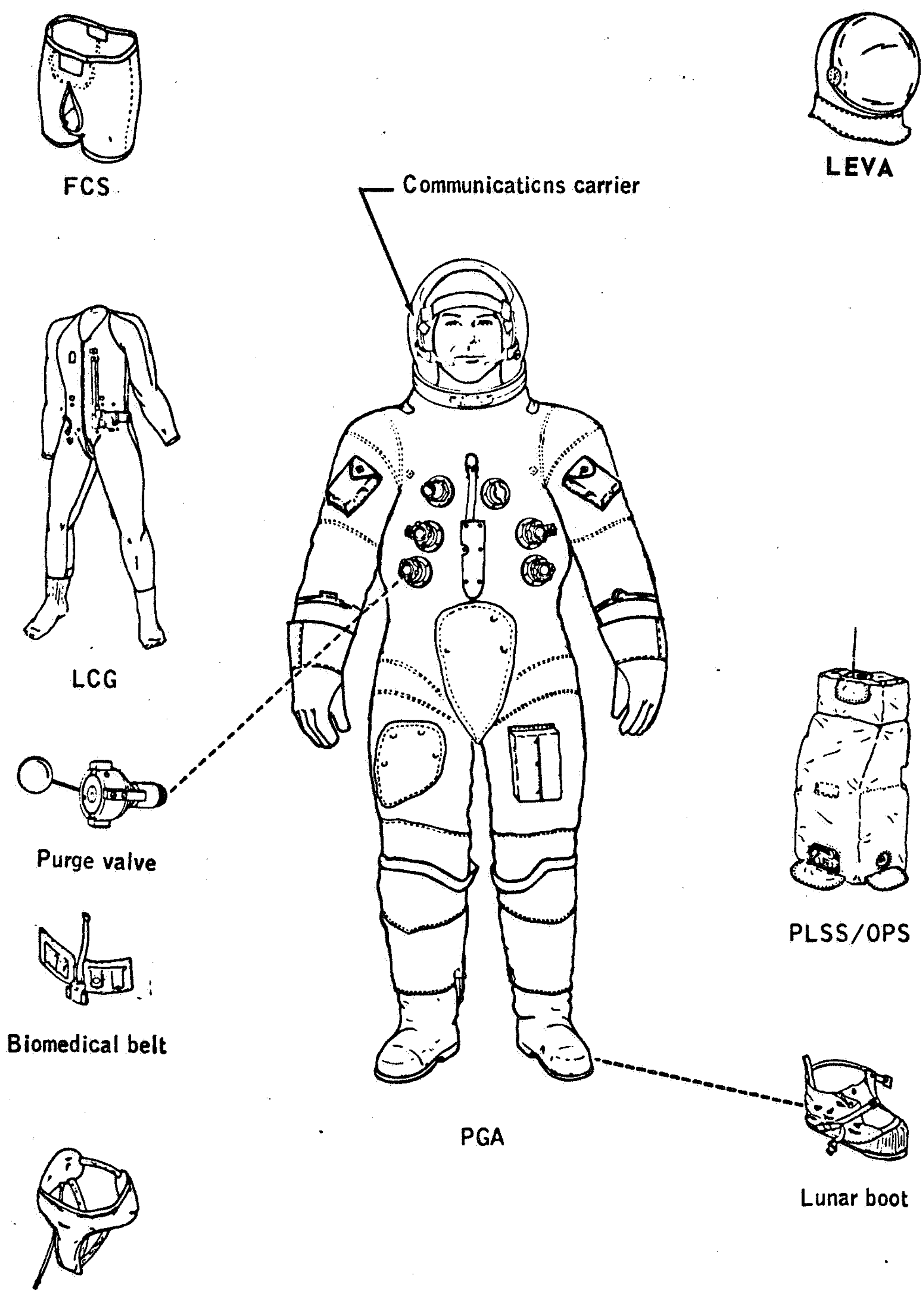


Figure 2.1-2 Extravehicular Mobility Unit Major Subsystems

2.2 Pressure Garment Assembly Configuration

The PGA consists of a pressure helmet, torso limb suit, gloves, boots, and various PGA controls. The function of the PGA is to enclose the crewman in a pressurized environment and permit performance of mission tasks in vacuum ambient pressure conditions. Two configurations of the PGA are utilized. The extravehicular (EV) PGA is worn by the LMP and CDR for use during EVA. The intravehicular (IV) PGA is worn by the CMP for intravehicular operations within the CM. A dimensional view of a typical PGA is shown in Figure 2.2-1.

2.2.1 Pressure Helmet

The pressure helmet shown in Figure 2.2-2 is a detachable transparent enclosure with provisions for feeding, drinking, and LEVA attachment.

2.2.2 Torso Limb Suit

The torso limb suit shown in Figure 2.2-3 incorporates a ventilation system shown in Figures 2.2-4 and 2.2-5 which provides a path for oxygen used for respiration, helmet defogging, and cooling. A biomedical injection patch is included to permit a crewman to self-administer a hypodermic injection.

2.2.3 Extravehicular PGA

The EV PGA shown in Figure 2.2-6 provides the crewman with a pressurized environment and thermal and micrometeoroid protection required when worn as a subassembly of the EMU for EVA portions of the mission. It incorporates the pressure helmet and torso limb suit discussed in sections 2.2.1 and 2.2.2 with the following additions.

(a) An integrated thermal micrometeoroid garment (ITMG), shown in Figure 2.2-7, provides protection against temperature extremes, micrometeoroid impact, and ultraviolet rays in addition to fire and abrasion resistance.

(b) A pressure relief valve protects the PGA from overpressurization.

(c) A removable purge valve, shown in Figure 2.2-8, located in the unused outlet gas connector, provides carbon dioxide washout and minimum cooling during contingency or emergency operation.

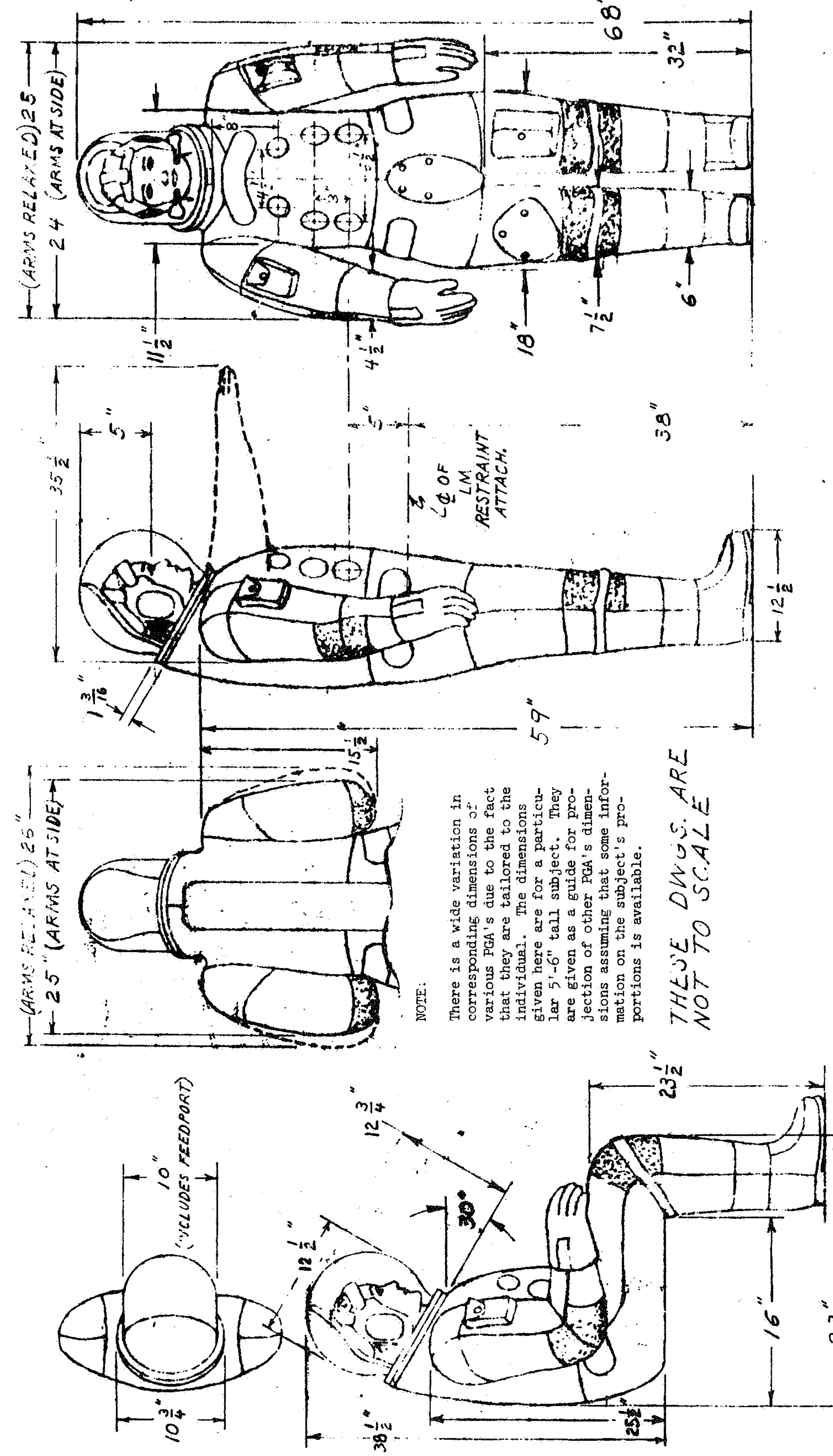
(d) Lunar boots, shown in Figure 2.2-9, provide thermal and abrasive protection for the PGA/ITMG boots during lunar surface operations.

(e) The EV Glove Assembly, shown in Figure 2.2-10, is a protective hand covering which is interfaced with the EV PGA prior to egress for extravehicular operations. The EV Glove provides increased thermal and abrasive protection during EVA. A cover glove constructed of a single layer of silicone coated Nomex is provided with each EV glove to provide increased abrasion protection during EV operation of the core driller. Each cover glove is fingertip-less to maintain the original tactility of the EV glove and has provision for utilizing the EV glove palm restraint access flap to secure the cover glove in such a way that access to the palm restraint strap is retained. The cover glove is required only for the core drilling operation and is expendable after that time.

(f) The lunar extravehicular visor assembly, shown in Figure 2.2-11, provides visual attenuation, thermal protection, and micrometeoroid impact protection during EVA. The LEVA also protects the pressure helmet from direct contact with the lunar surface during accidental impact.

2.2.4 Intravehicular PGA

The IV PGA shown in Figure 2.2-12 provides the crewman with a pressurized environment when worn as a subassembly of the EMU for IV portions of the mission. Beside incorporating the pressure helmet and torso limb suit discussed in sections 2.2.1 and 2.2.2, it incorporates an IV cover layer. The IV cover layer provides abrasion and fire protection for intravehicular activity.



NOTE:

There is a wide variation in corresponding dimensions of various PGA's due to the fact that they are tailored to the individual. The dimensions given here are for a particular 5'-6" tall subject. They are given as a guide for projection of other PGA's dimensions assuming that some information on the subject's proportions is available.

Figure 2.2-1 Typical A7L PGA Dimensions (pressurized) for a $5\frac{1}{2}$ foot tall crewman

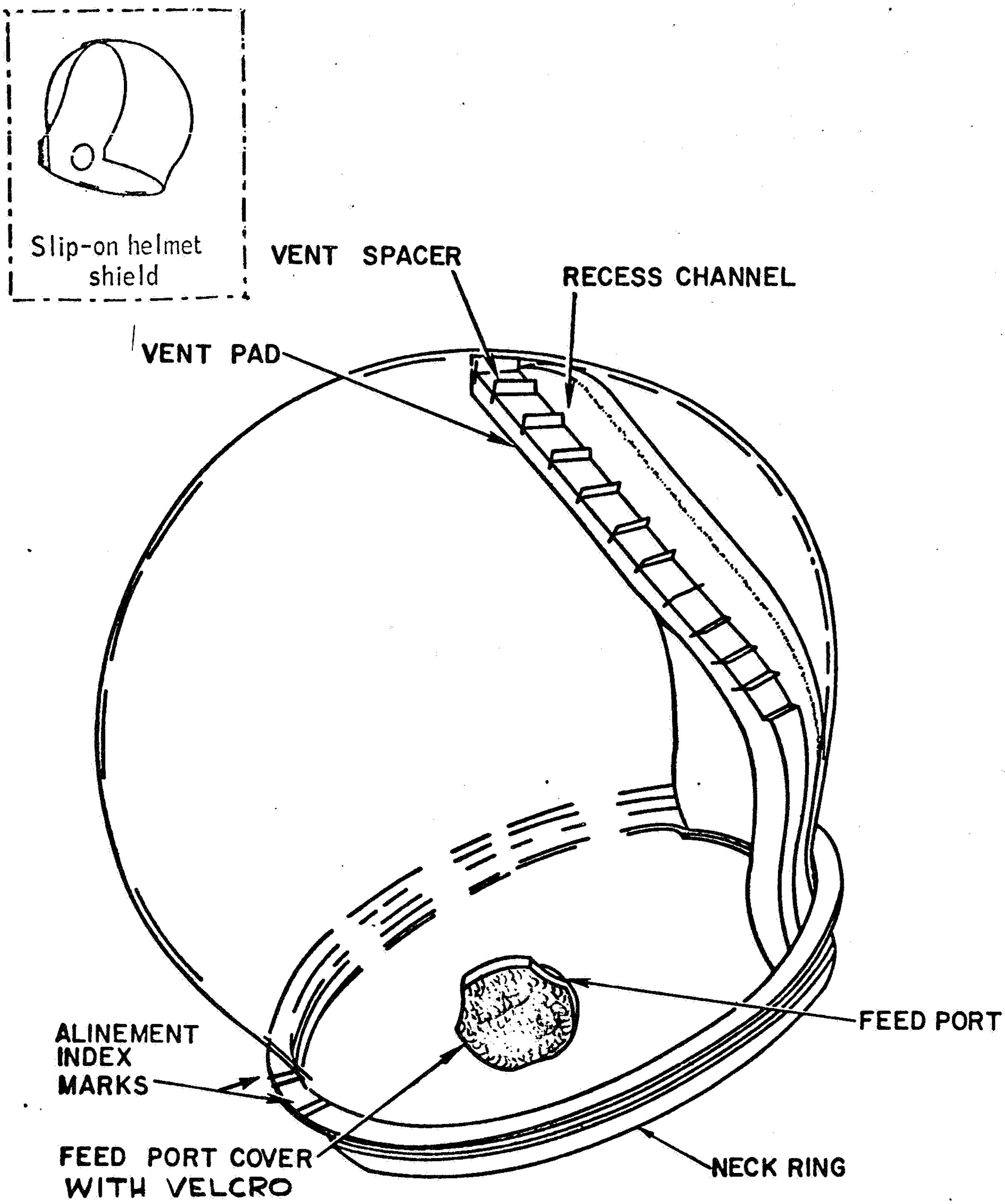


Figure 2.2-2 Pressure Helmet

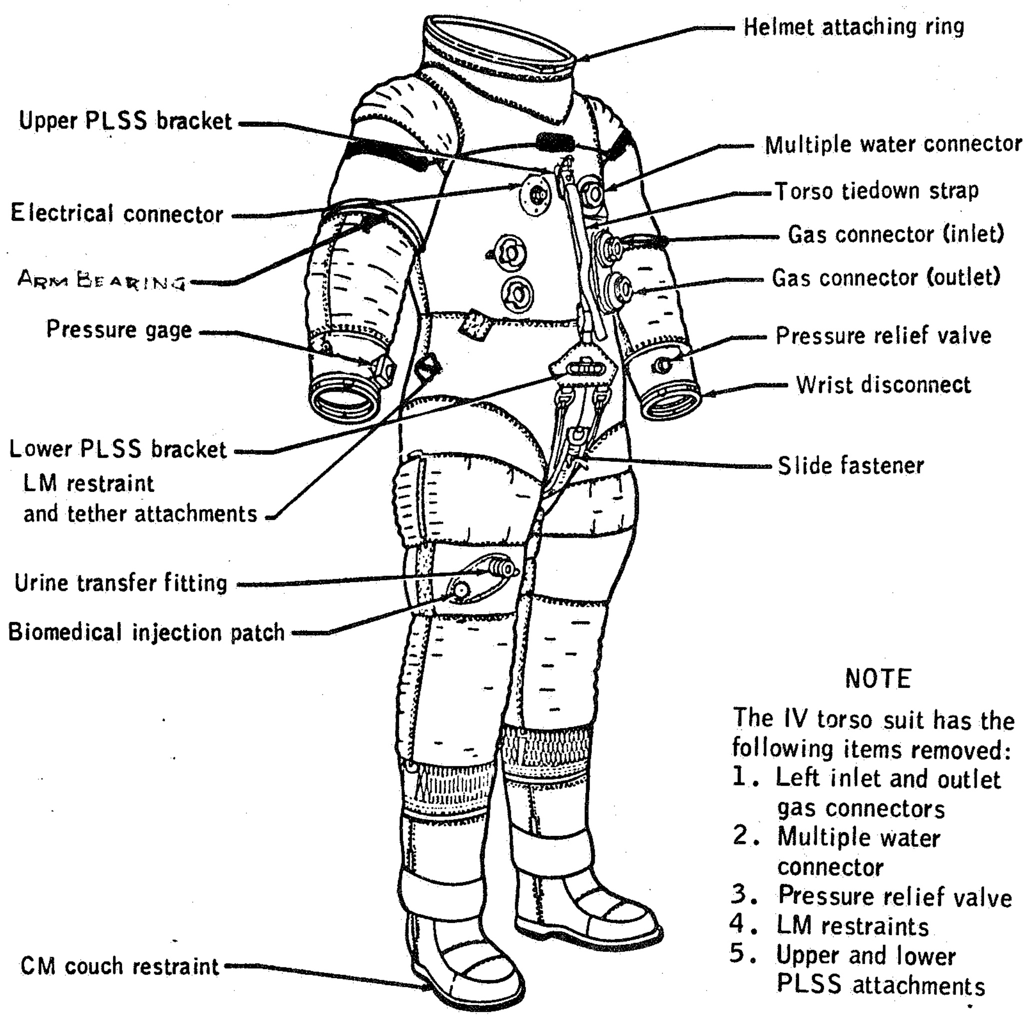


Figure 2.2-3 Extravehicular Configuration of the Torso Limb Suit

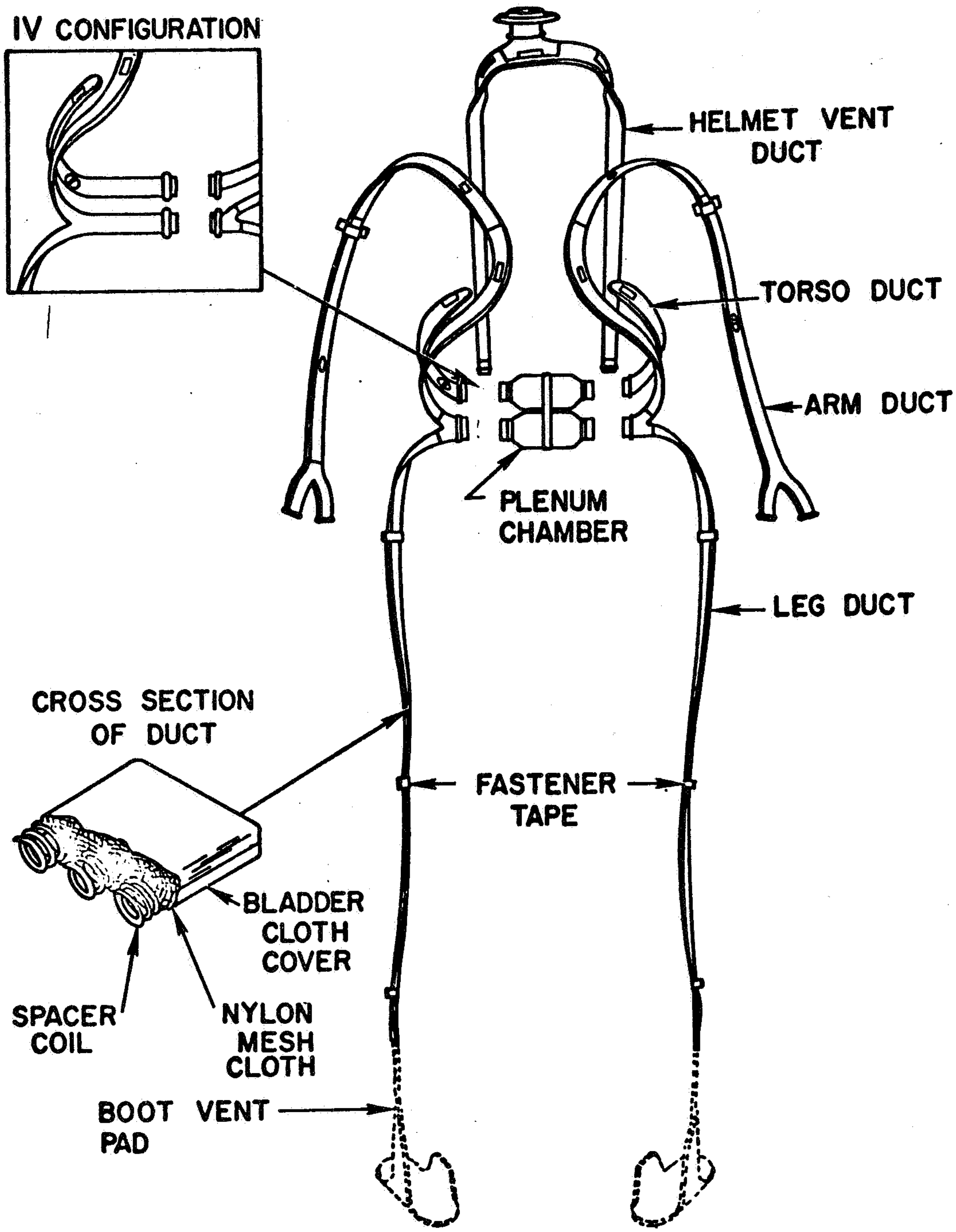


Figure 2.2-4 Ventilation Systems of the Torso Limb Suit

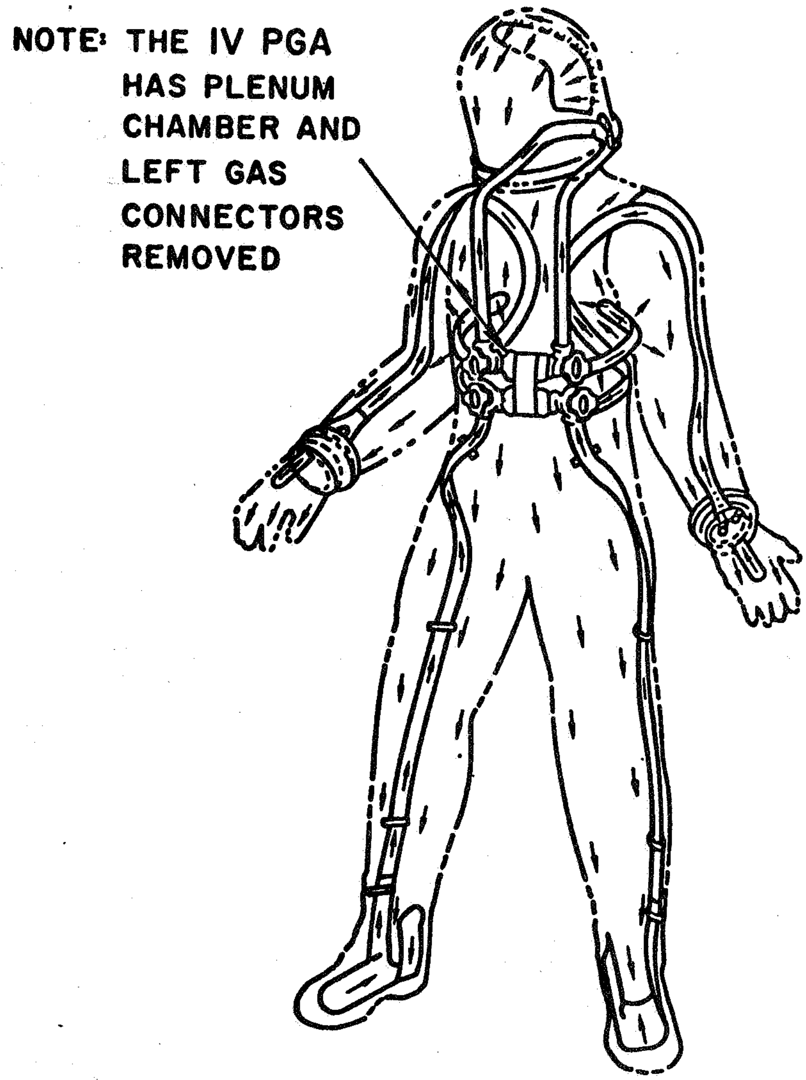


Figure 2.2-5 Ventilation Flow Diagram

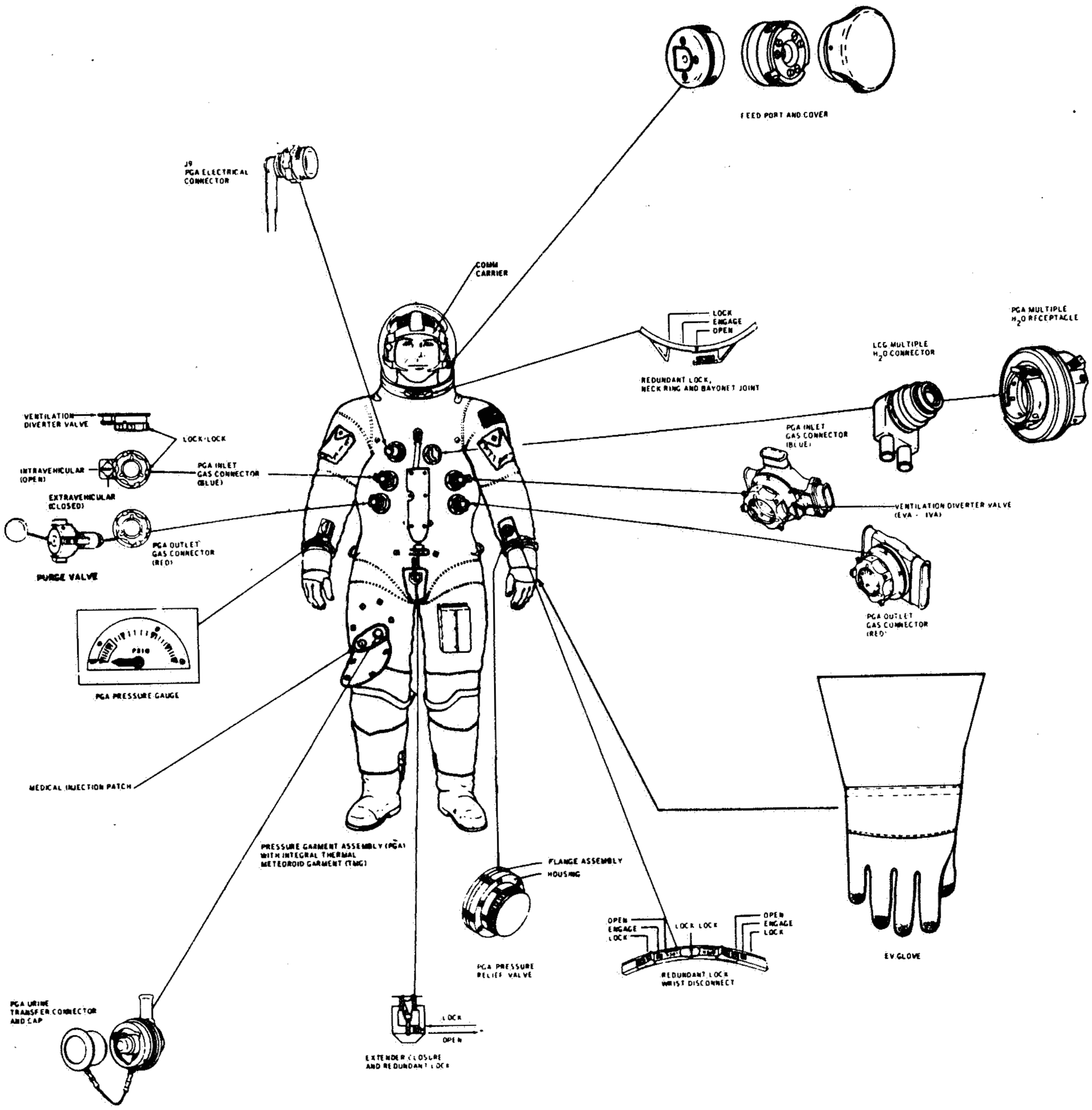


Figure 2.2-6 Extravehicular PGA Configuration

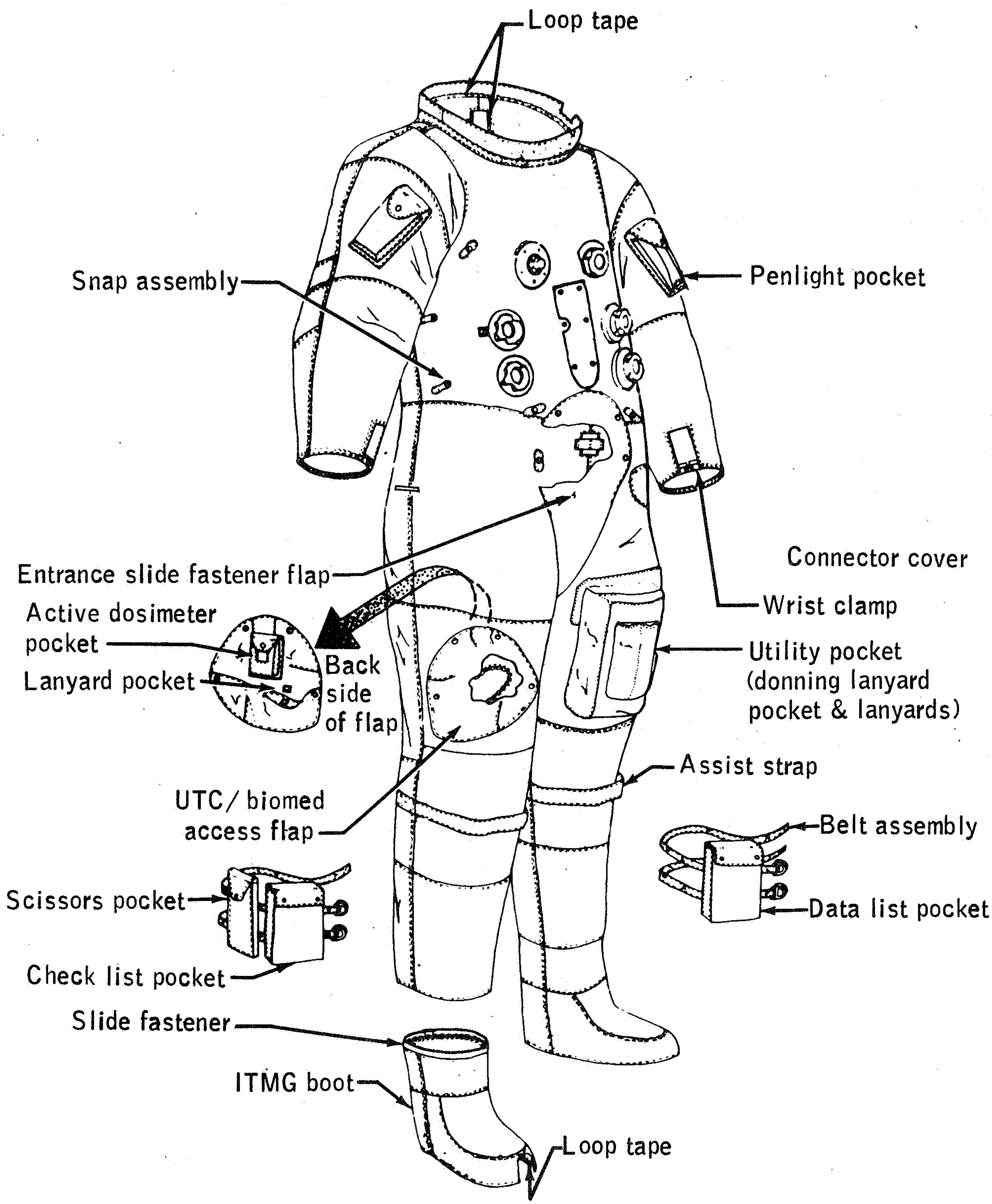


Figure 2.2-7 Integrated Thermal Micrometeoroid Garment

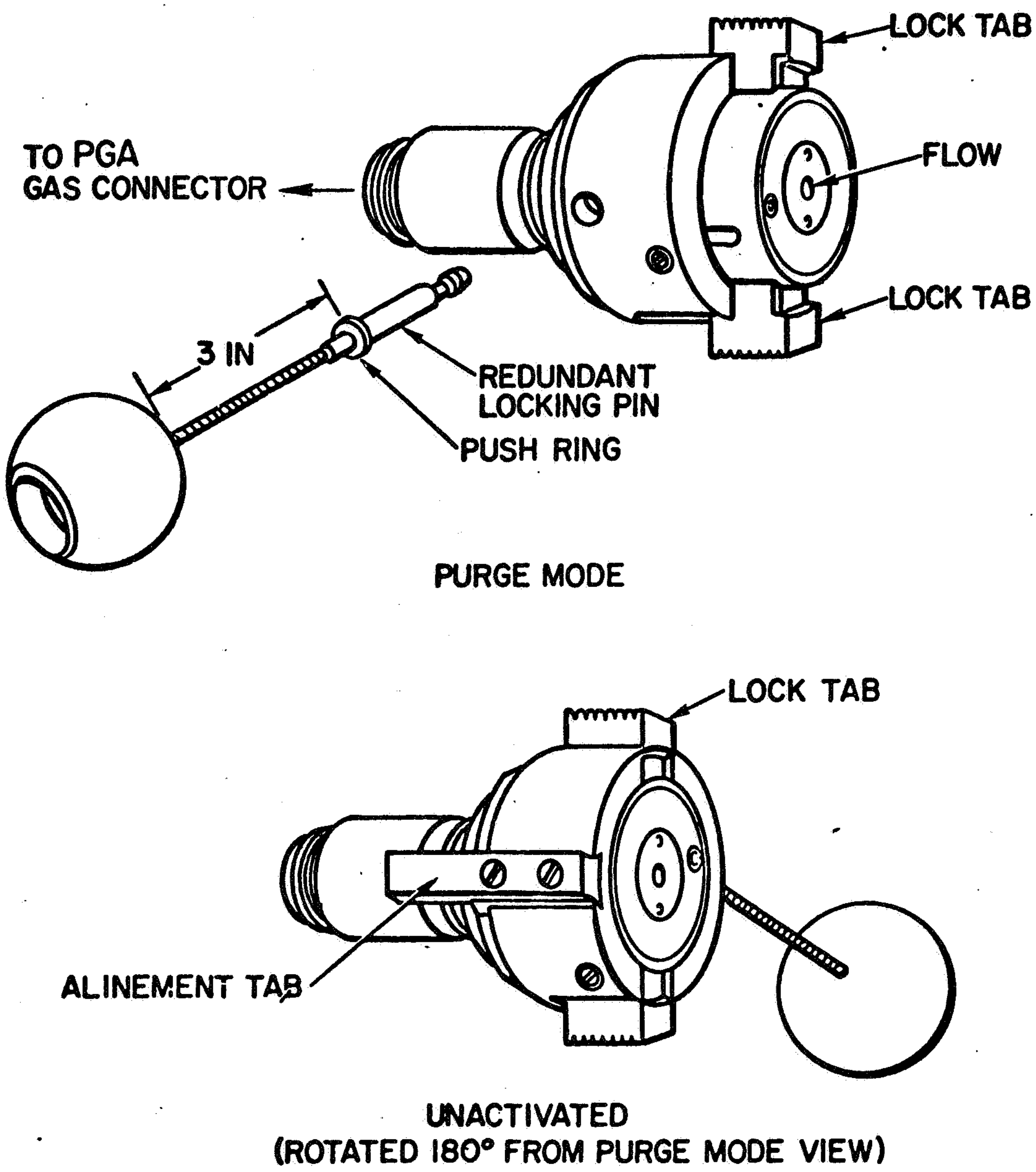


Figure 2.2-8 Purge Valve

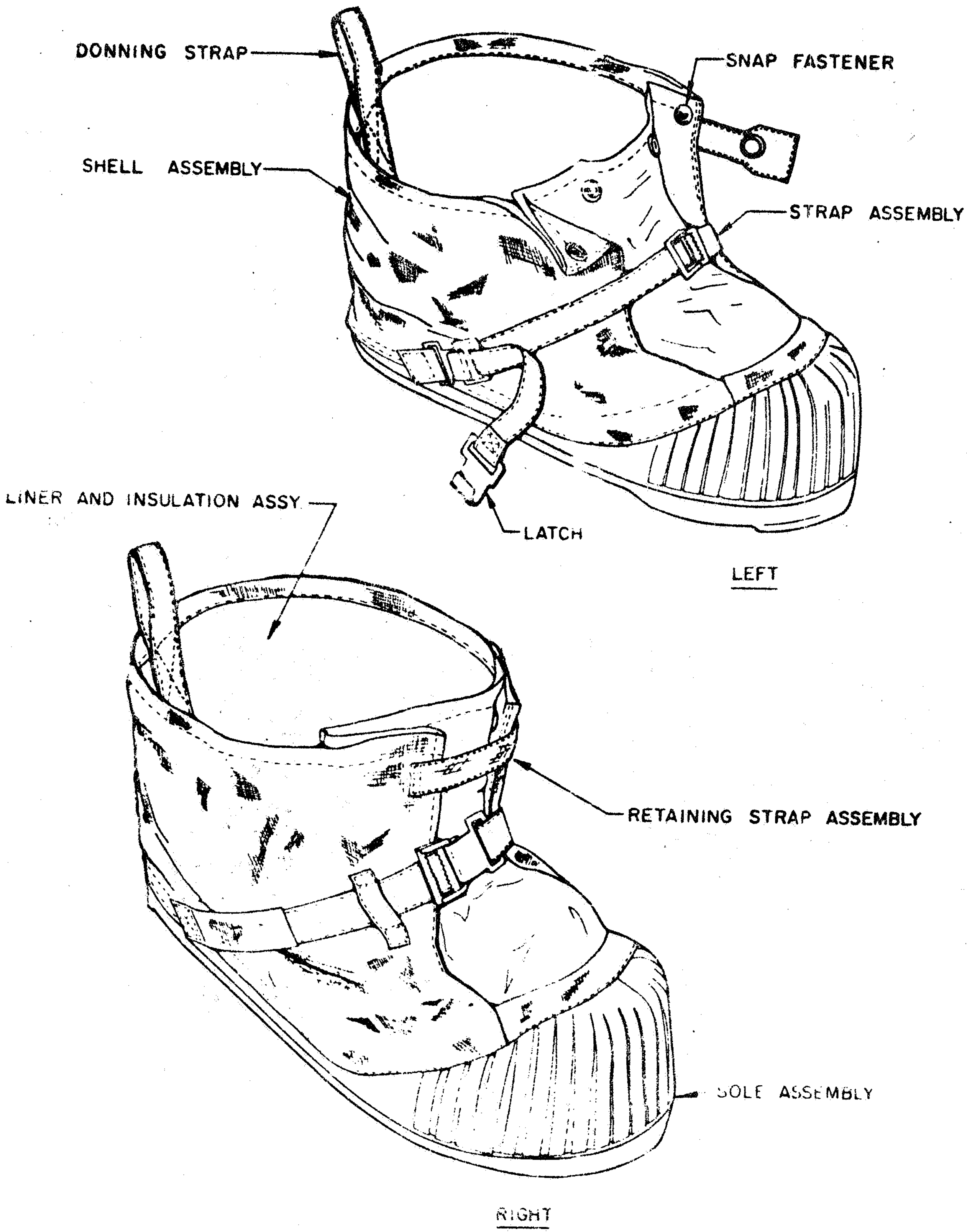


Figure 2.2-9 Lunar Boots

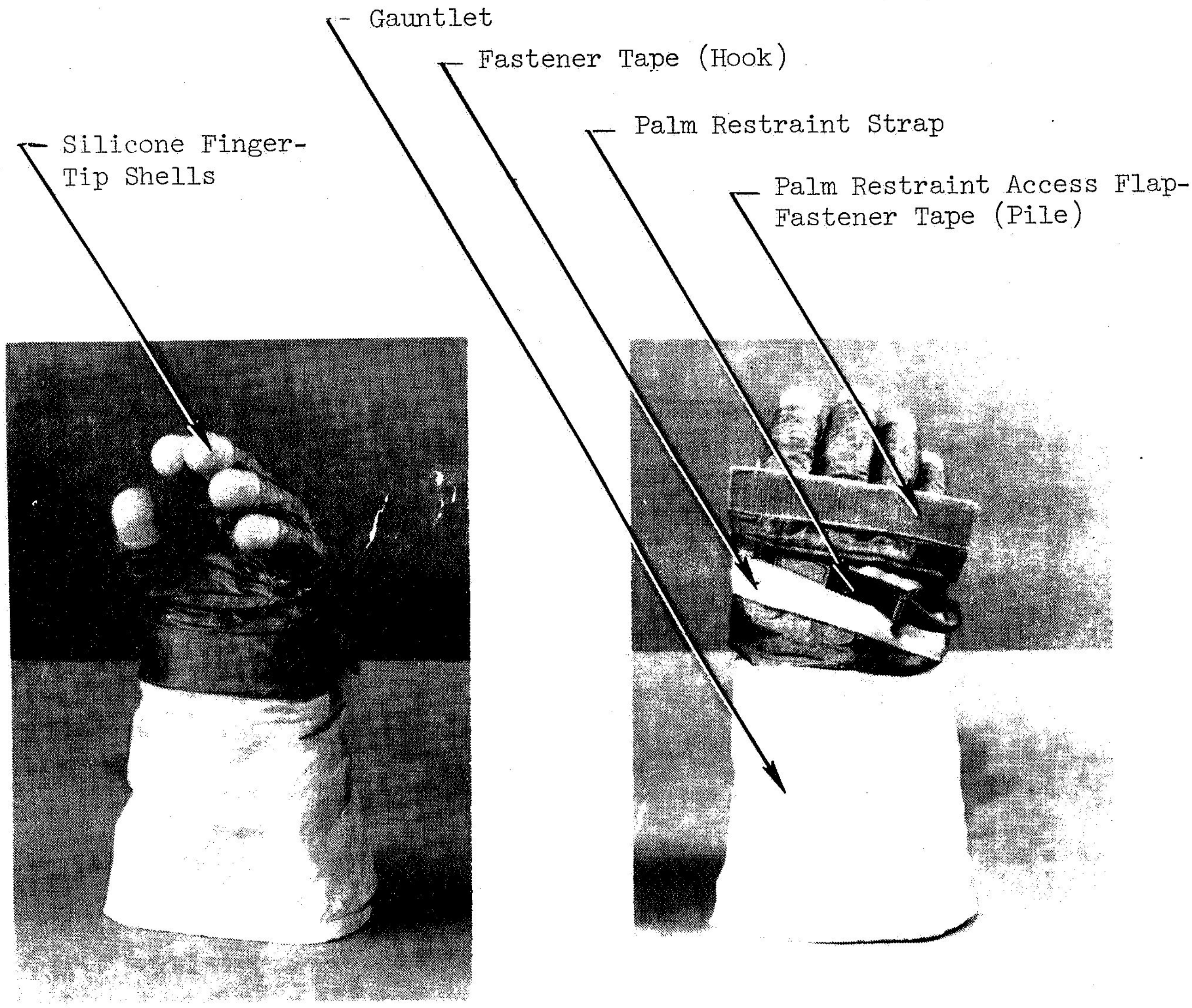


Figure 2.2-10 EV Glove

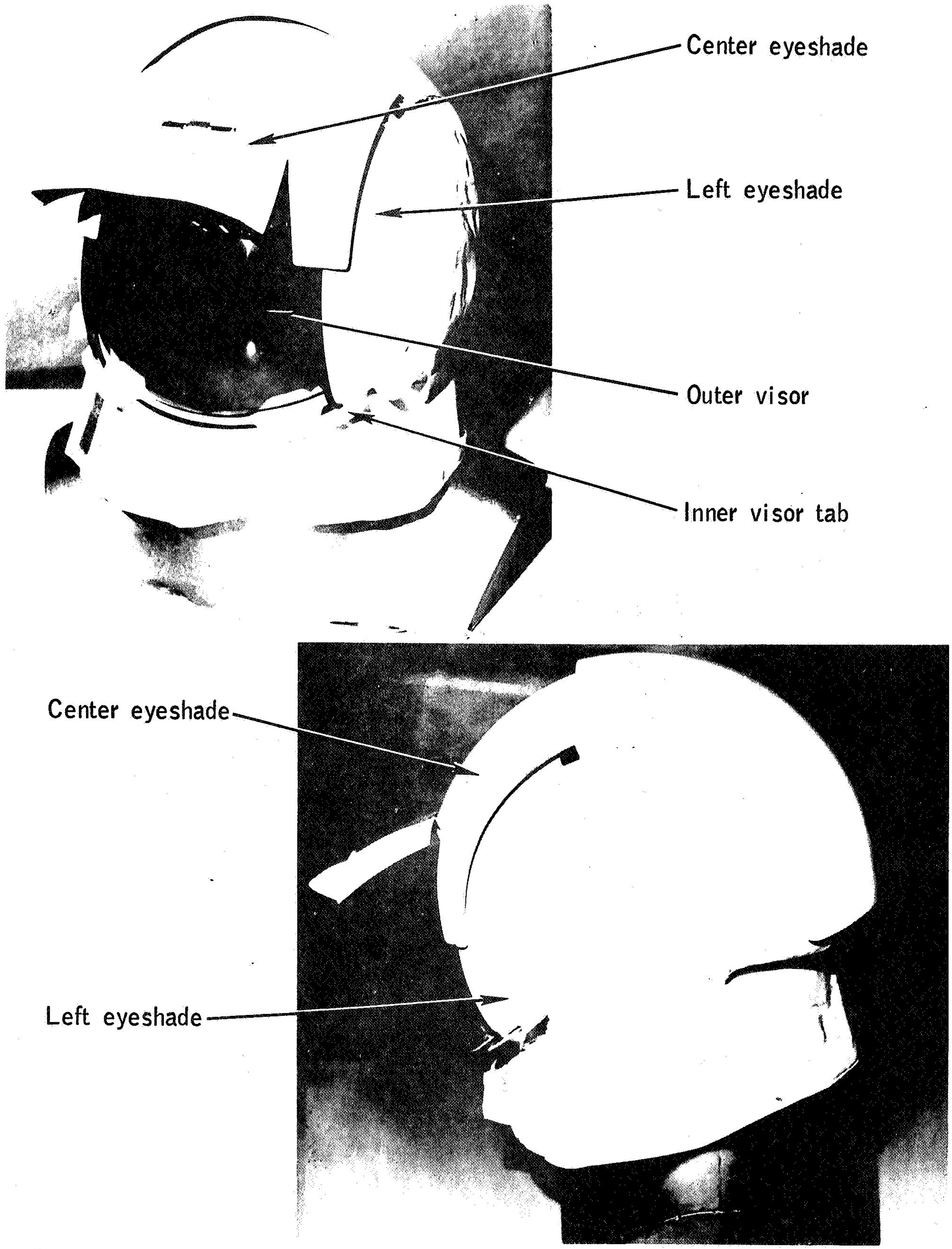


Figure 2.2-11 Lunar Extravehicular Visor Assembly

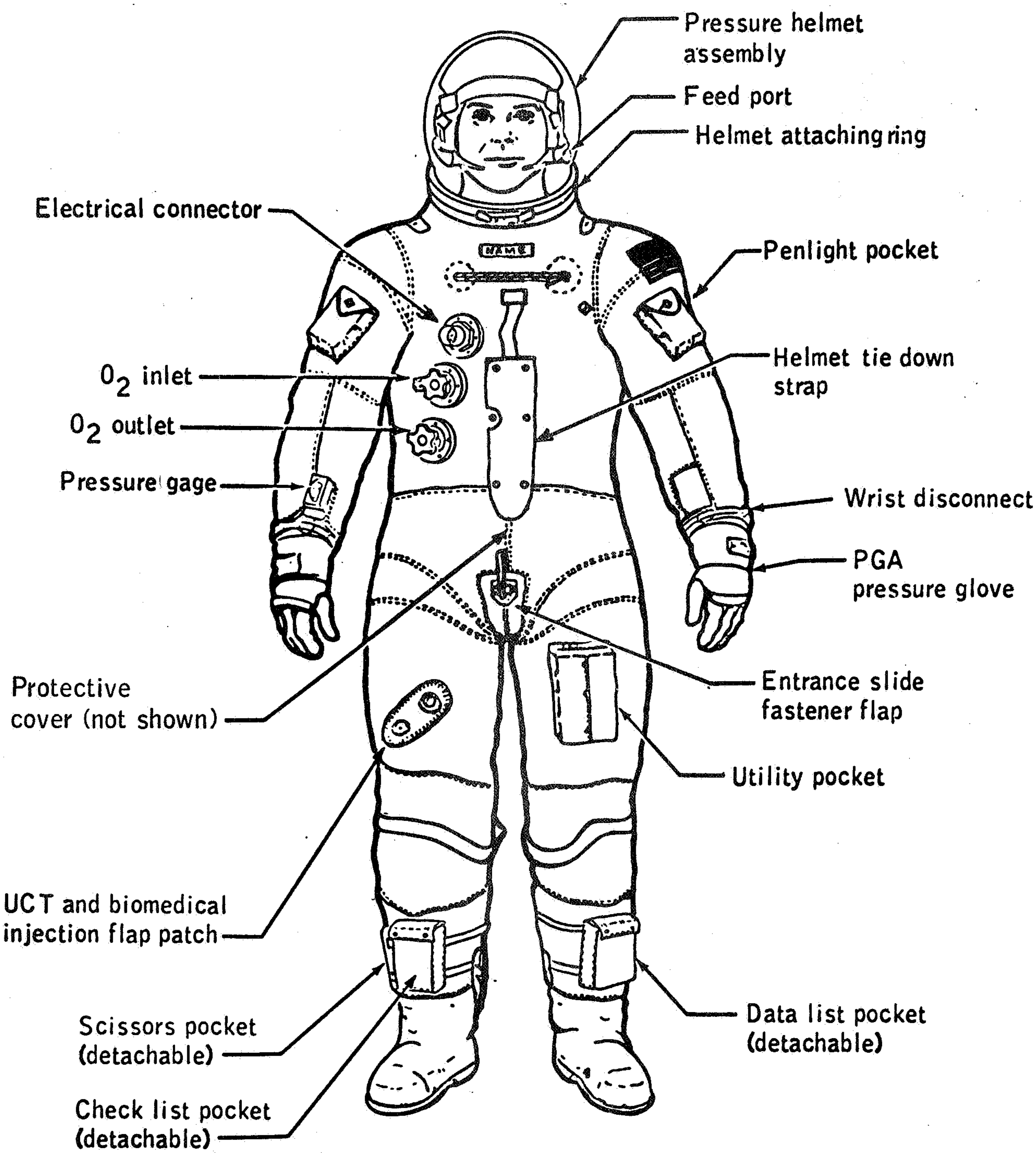


Figure 2.2-11 Intravehicular PGA Configuration

2.3 CONSTANT WEAR GARMENT

The constant wear garment, shown in Figure 2.3-1, is a cotton fabric undergarment worn next to the skin under the PGA or inflight coverall garment during intravehicular CM operation. It provides general comfort and perspiration absorption, and supports the bioinstrumentation system.

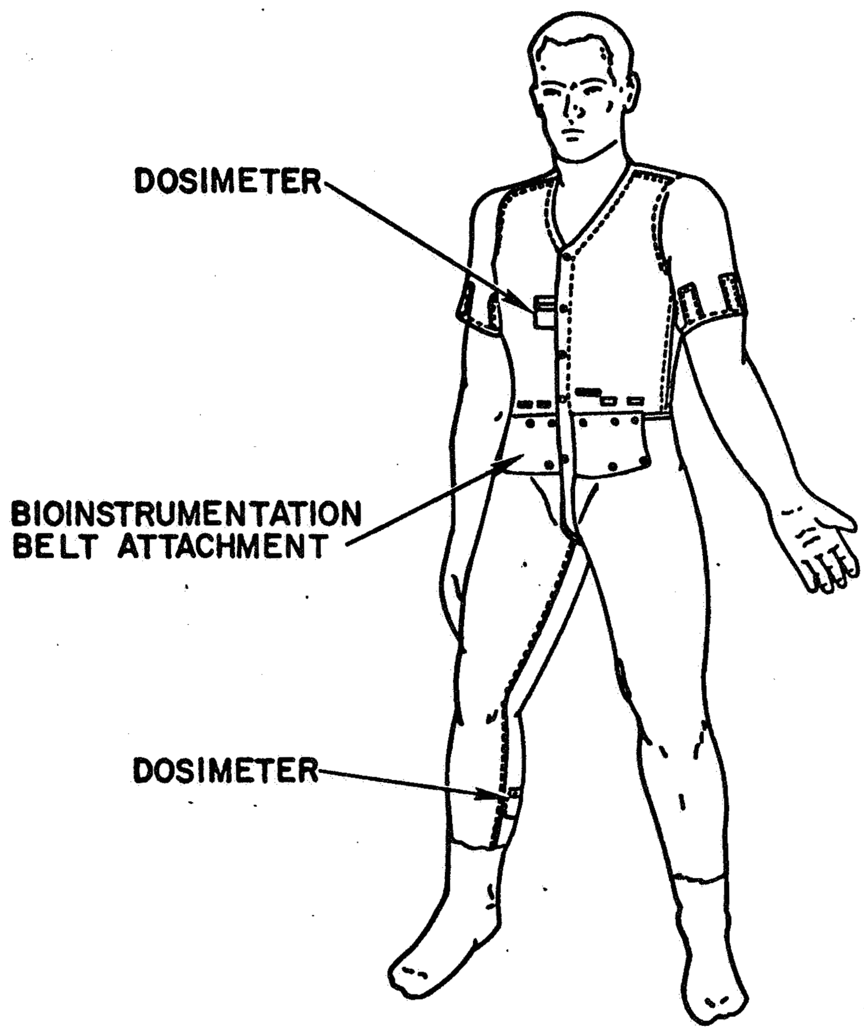


Figure 2.3-1 Constant Wear Garment

2.4 Liquid Cooling Garment

The liquid cooling garment configuration is shown in Figures 2.4-1 and 2.4-2. The LCG is worn by the LM crewman (CDR and LMP) during all LM operations, and during all EVA portions of the mission, but under normal circumstances, is operational only when used in conjunction with the PLSS. The LCG provides a means for circulation of water over the crewman's body for removal of metabolic heat.

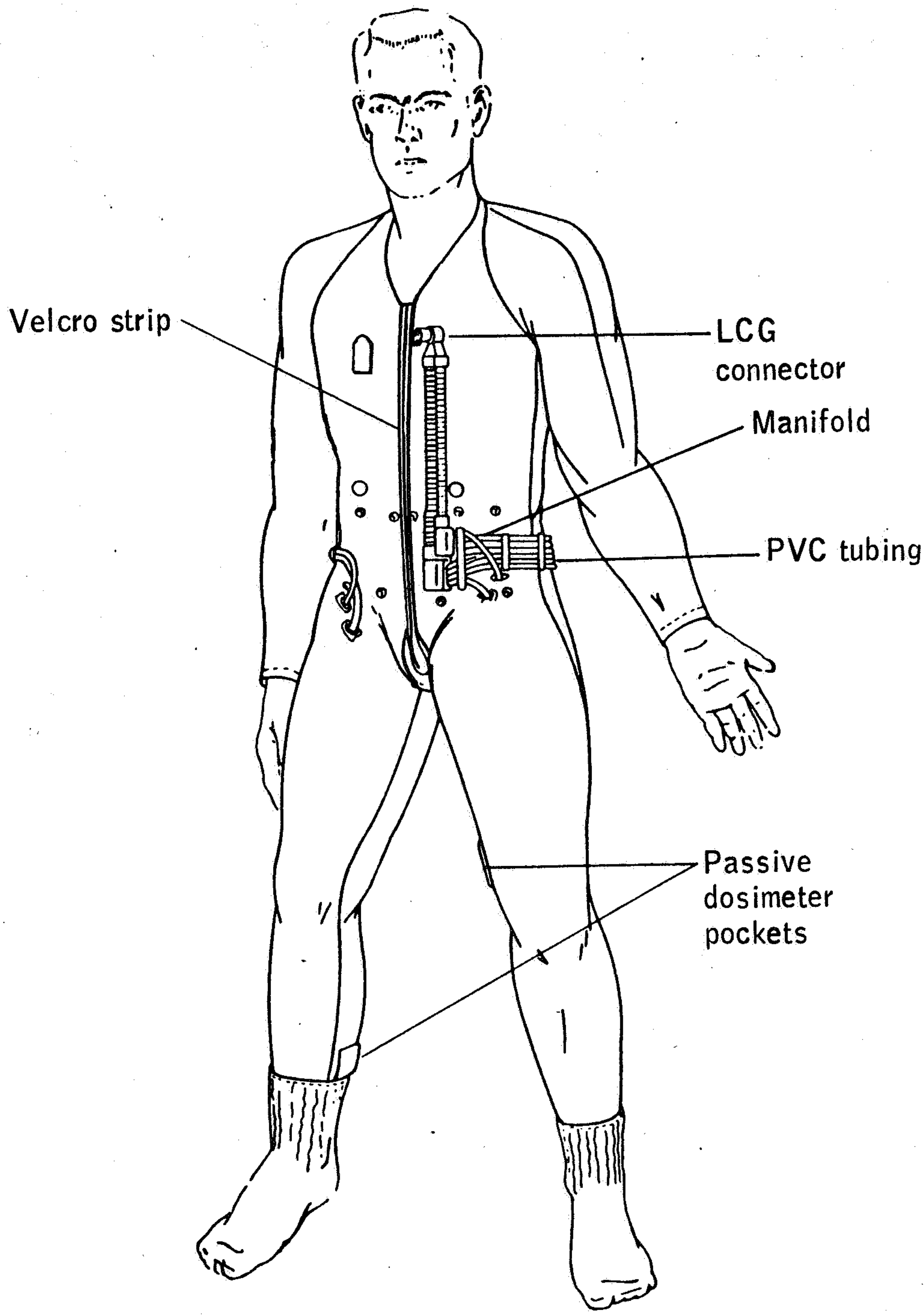


Figure 2.4-1 Liquid Cooling Garment

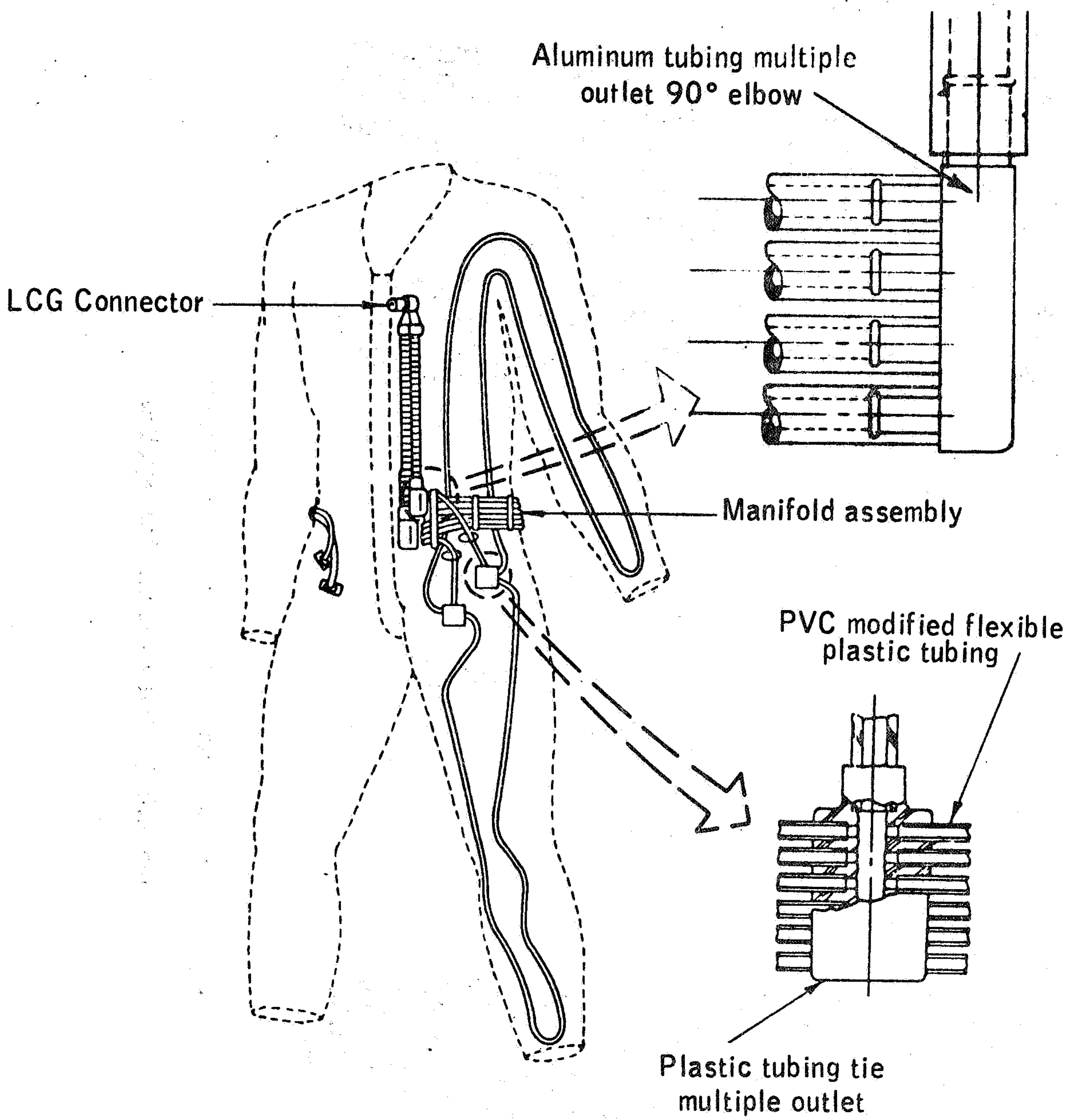
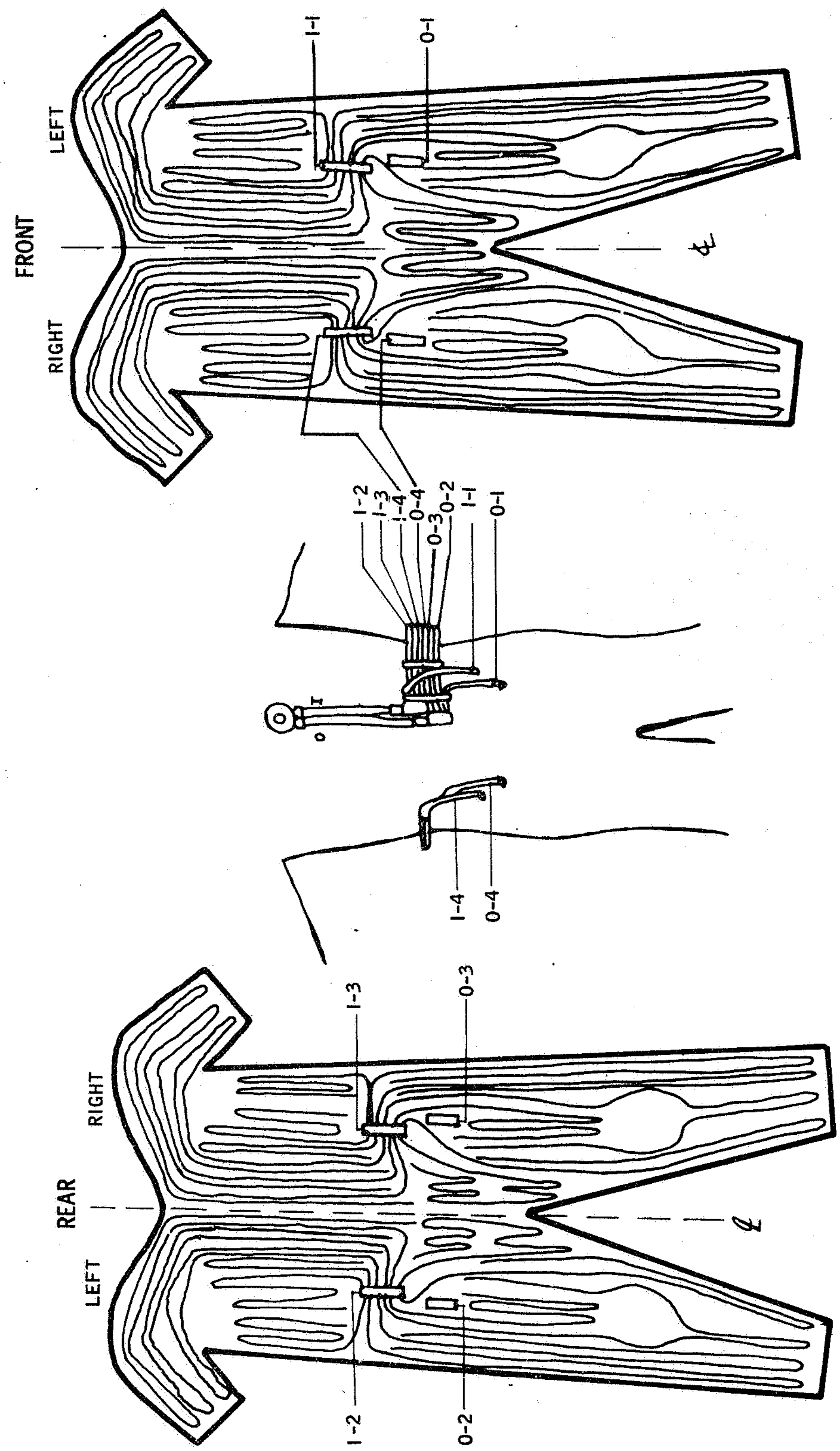


Figure 2.4-2 Coolant System of the LCG



1- : Inlet Line   O- : Outlet Line

Figure 2.4-3 LCG Circulation System

2.5 Urine Collection and Transfer Assembly

The UCTA, shown in Figure 2.5-1, collects and provides intermediate storage of crewman's urine during launch, EVA, or emergency modes when the spacecraft waste management system cannot be used.

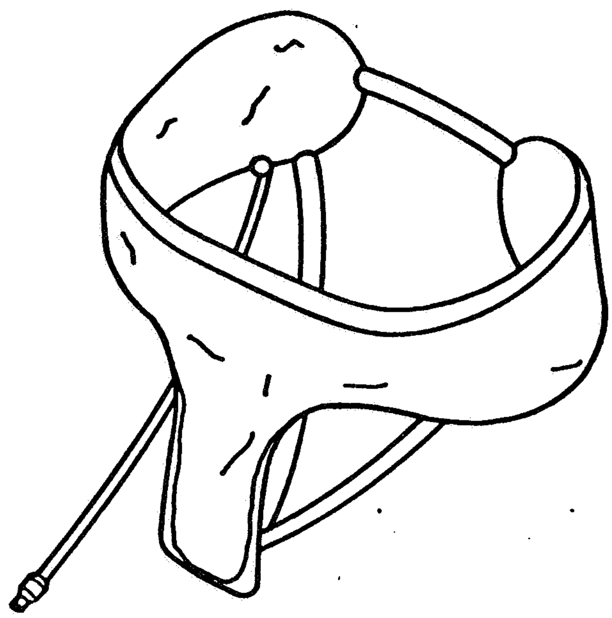


Figure 2.5-1 Urine Collection Transfer Assembly

2.6 Biomedical Instrumentation System

The BIS provides a means for monitoring the biomedical status of the astronauts during all phases of the Apollo mission.

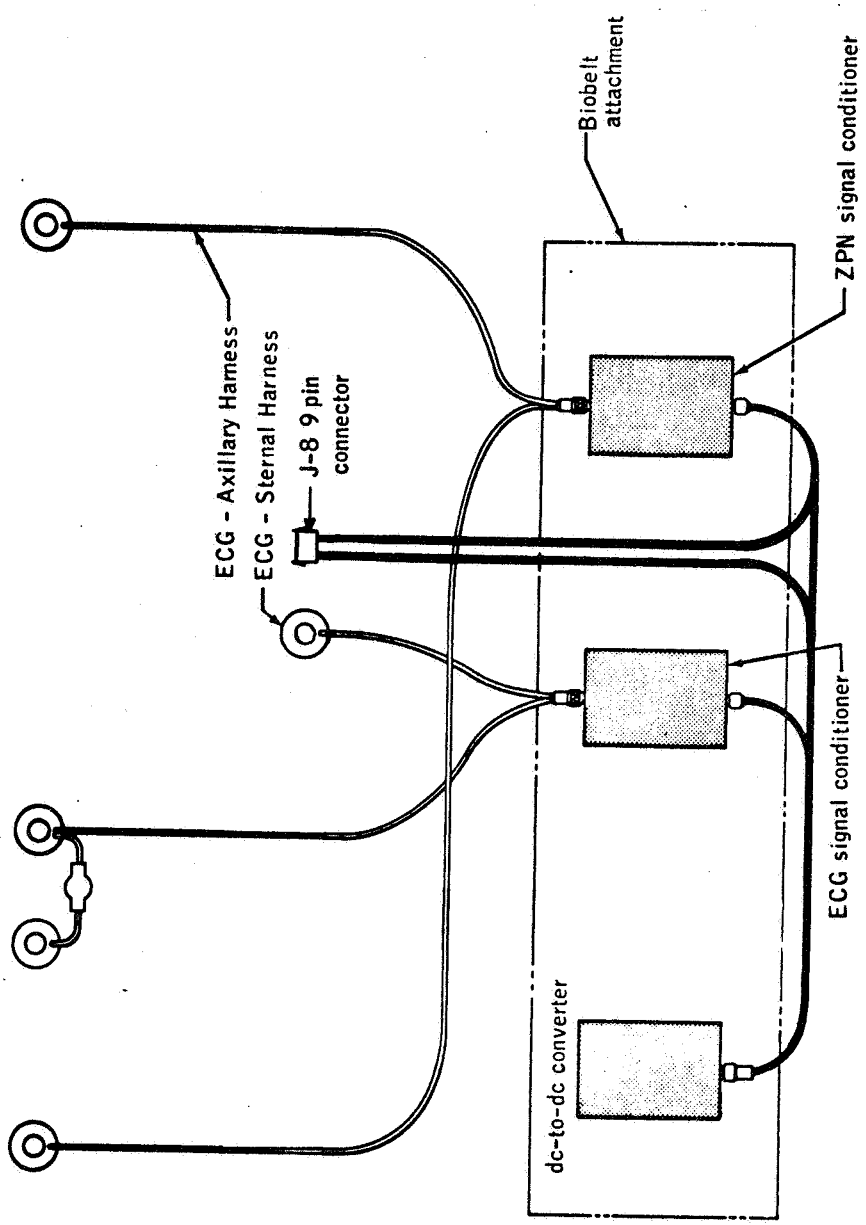


Figure 2.6-1 Bioinstrumentation System

2.7 Portable Life Support System Configuration

The configuration of the PLSS is shown in Figures 2.7-1 through 2.7-6. The function of the PLSS is to provide life support, communications, and telemetry during extravehicular portions of the Apollo mission. The following life support functions are performed:

(a) Pressure control
(b) Breathing oxygen supply
(c) Ventilation
(d) Humidity control
(e) Contaminant control
(f) Thermal control

The PLSS, ahown schematically in Figure 2.7-7, consists of the following subsystems jointly satisfying the performance requirements of the PLSS. A brief description of each subsystem follows.

2.7.1 Communication and Telemetry

Three modes of two-way voice communications are provided between the PLSS and the LM for relay to MSFN. In addition, an FM link is provided directly between the two EV crewmen. The system performance of each PLSS is monitored in eight areas with the information commutated on one subcarrier unique to each crewman, and telemetered to earth via the LM. In addition, the EKG information for each crewman is sampled continuously and telemetered to earth via the LM. The various combinations of communications modes are pictorially represented in Figures 2.7-8 through 2.7-10. An audible tone is also provided to alert the EV crewman of the occurrence of one or more of four unsafe conditions.

2.7.2 Electrical Supply and Distribution Subsystem

The PLSS electrical supply and distribution subsystem consists of a replaceable power source (battery) and the necessary controls, terminal boxes, current limiters, and wiring required to satisfy the PLSS electrical requirements.

2.7.3 Oxygen Ventilating Circuit

The Oxygen Ventilation Circuit circulates a fresh, refrigerated oxygen supply through the PGA. The O_2 from the PGA passes to the contaminant control assembly where odors, foreign particles, and CO_2 are removed. The O_2 passes then to a sublimator where it is cooled. From the sublimator, it passes to a water separator, then to a fan which circulates the O_2 back to the PGA along with makeup O_2.

2.7.4 Water Transport Loop

The water transport loop circulates water through the LCG for the absorption of metabolic heat and dissipates the heat in the PLSS.

2.7.5 Feedwater Supply Loop

The feedwater supply loop provides a supply of expendable water used for the dissipation by sublimation of all heat entering into or generated by the EMU.

2.7.6 Primary Oxygen Subsystem

The primary oxygen subsystem provides a rechargeable supply of gaseous oxygen and maintains PGA and ventilation loop pressures at 3.70 to 4.00 psia during normal extravehicular operation. If leakage goes out of specification, causing a high O_2 flow, the pressure may drop to 3.5 psia. The primary oxygen subsystem contains one pressure bottle with a volume of 378 cubic inches.

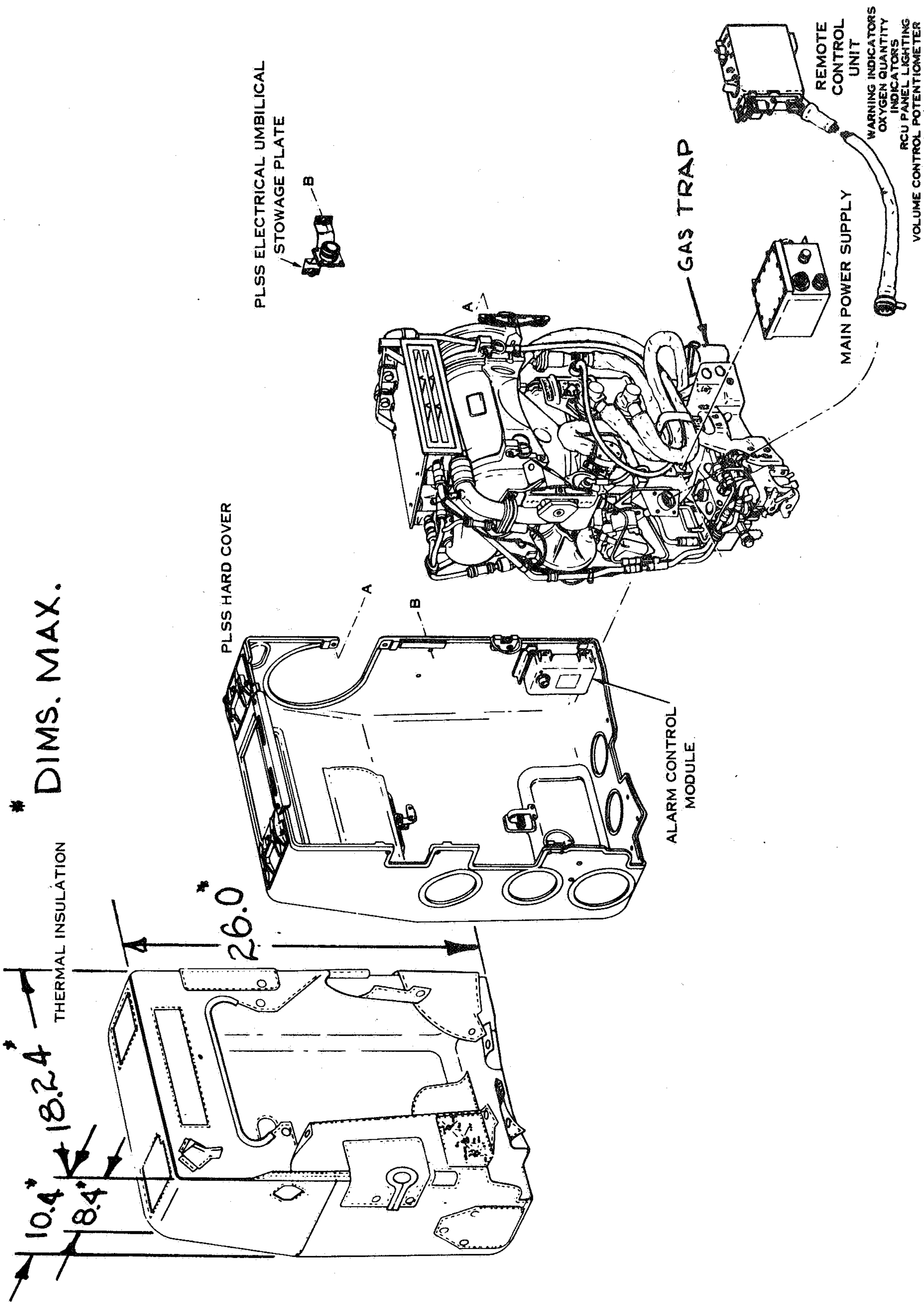


Figure 2.7-1 Portable Life Support System (PLSS)

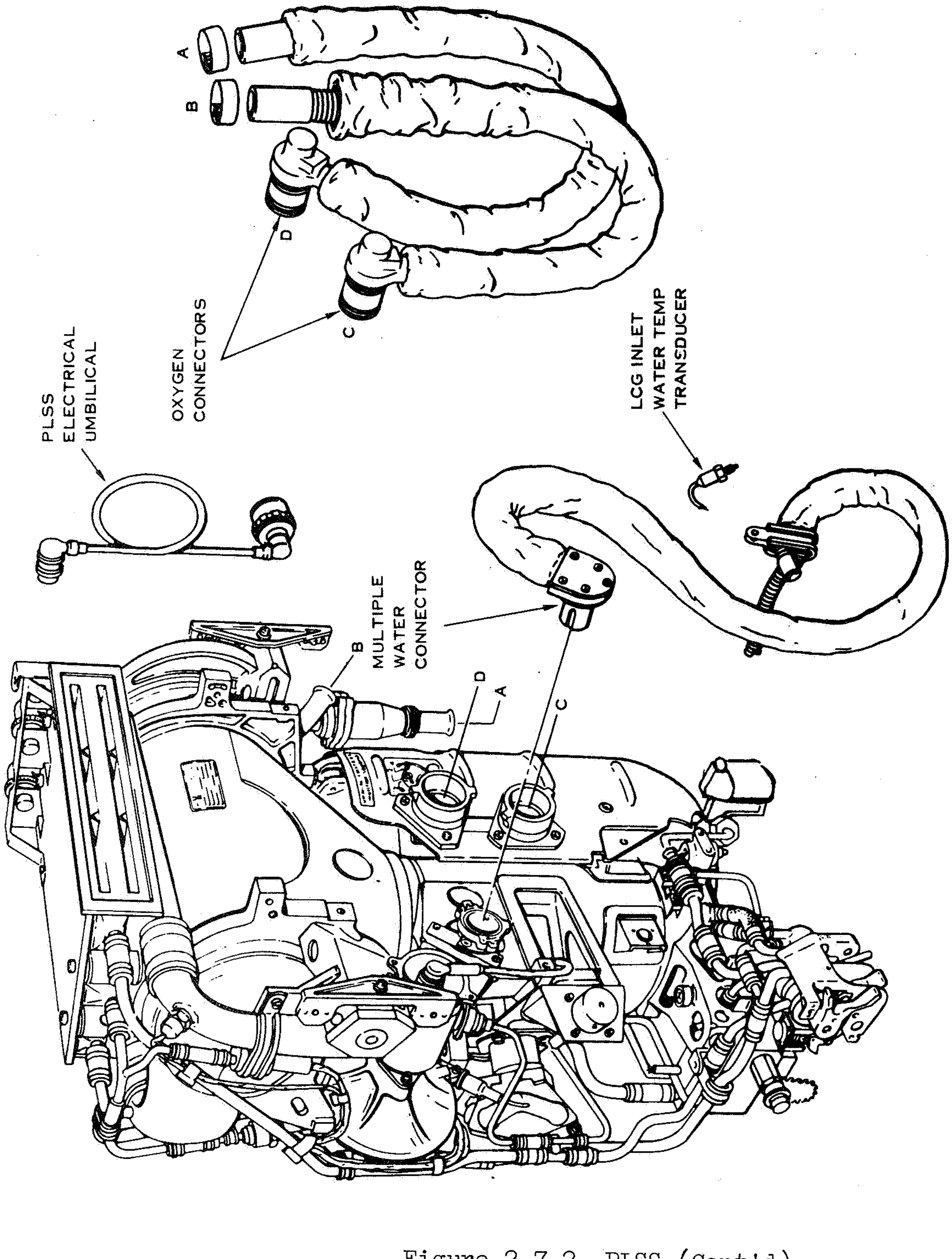
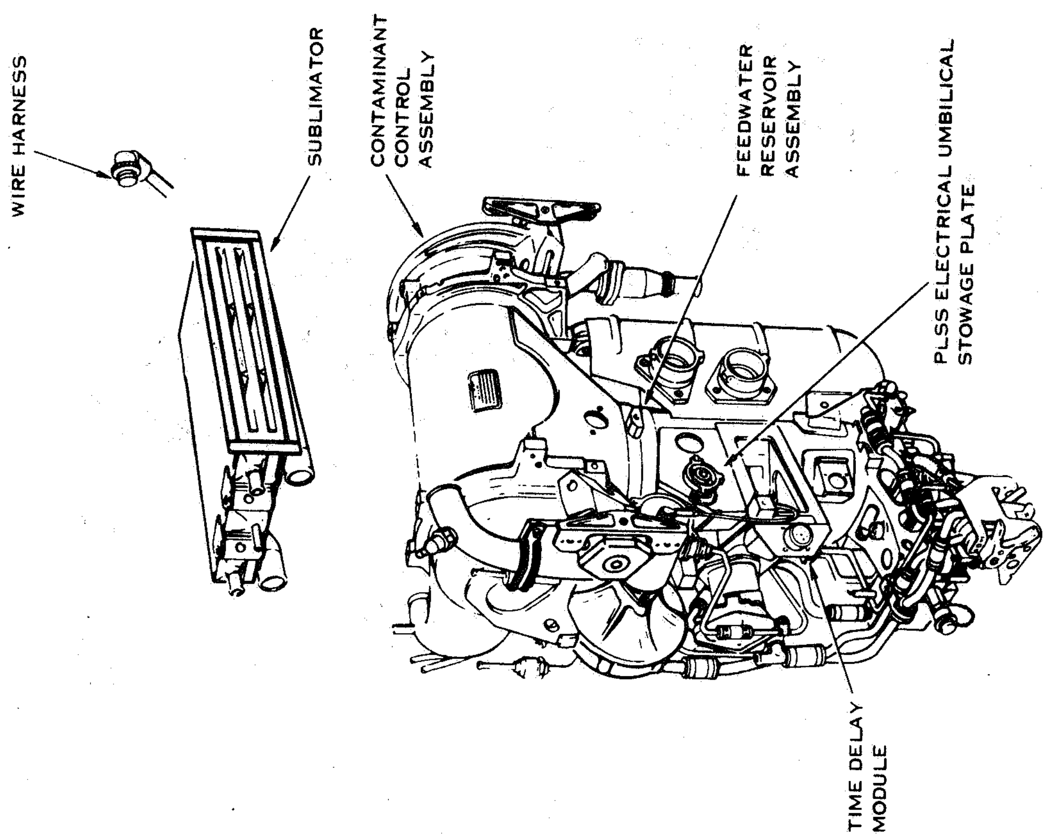


Figure 2.7-2 PLSS (Cont'd)

PLSS SV706100-6



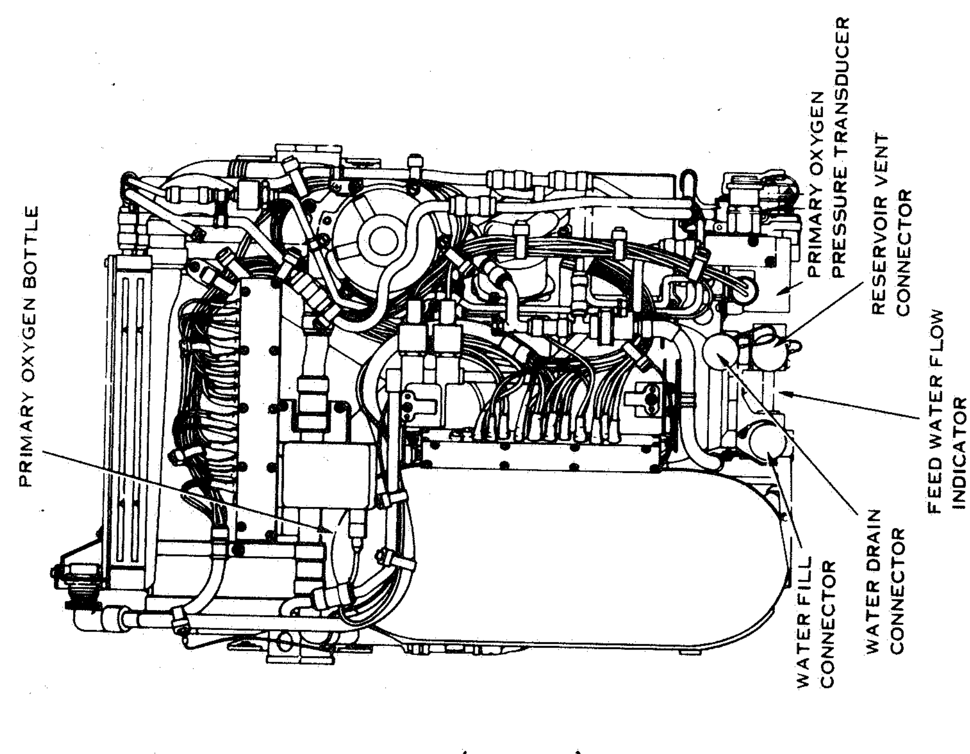


Figure 2.7-3 PLSS (Cont'd)

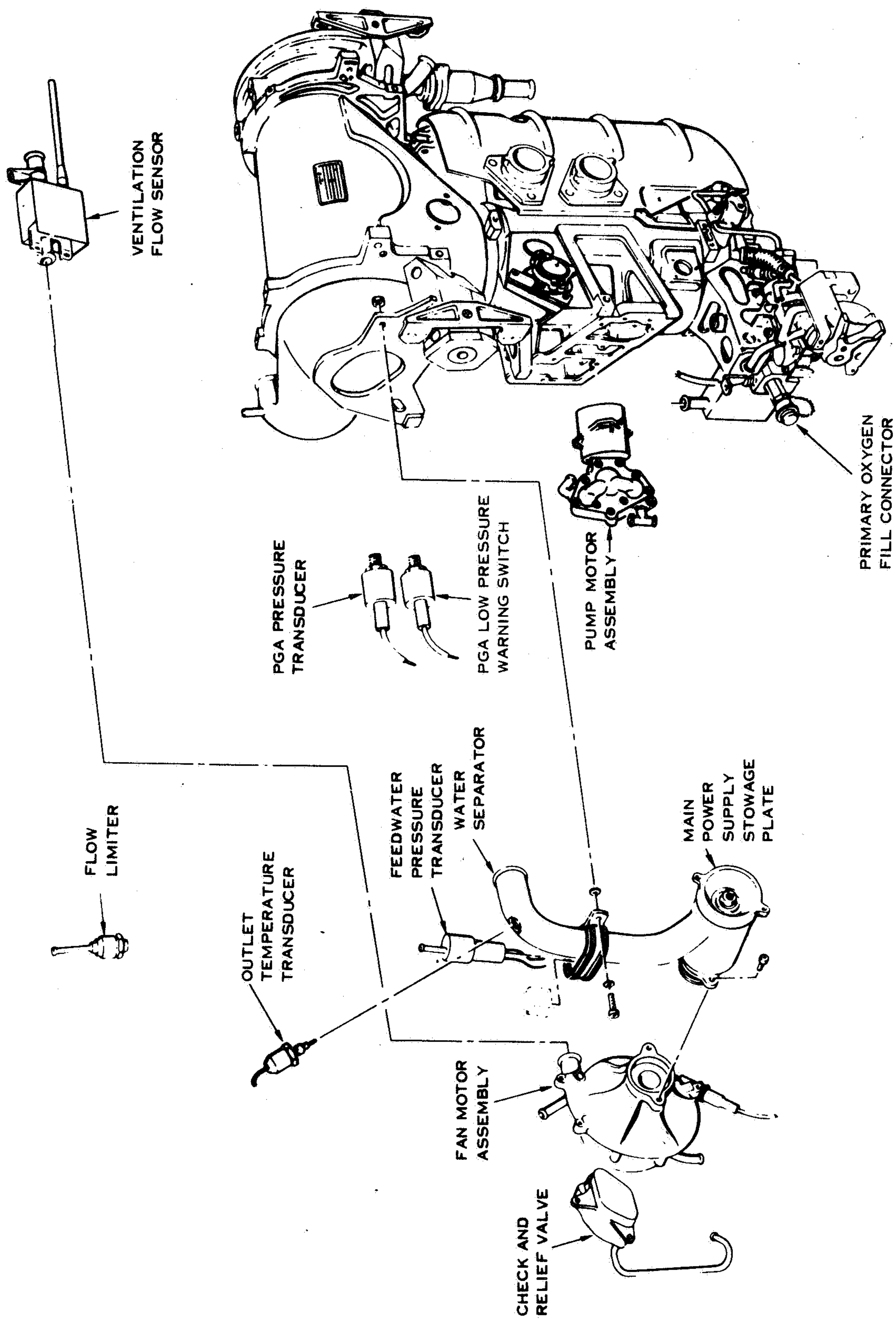


Figure 2.7-4 PLSS (Cont'd)

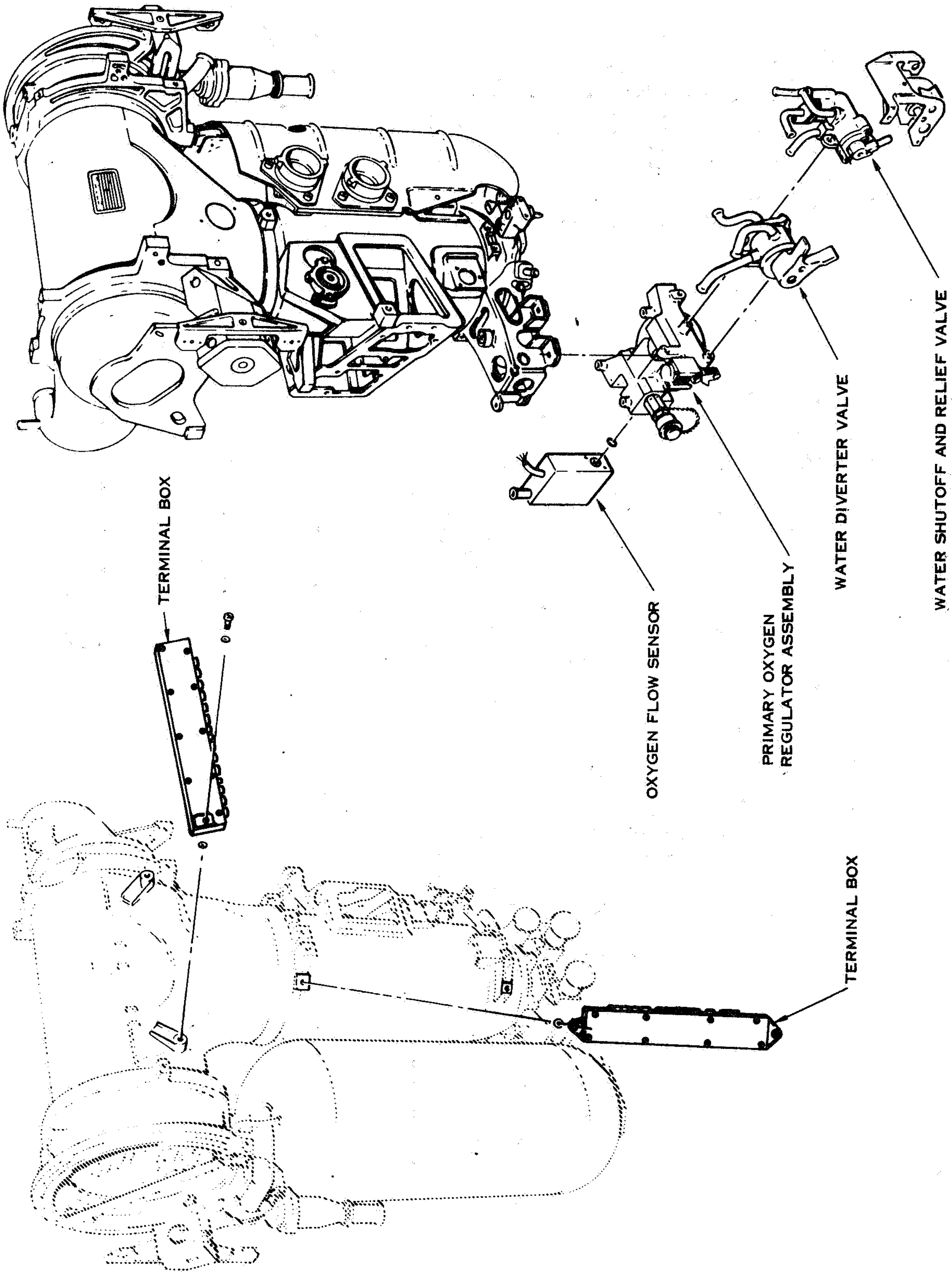


Figure 2.7-5 PLSS (Cont'd)

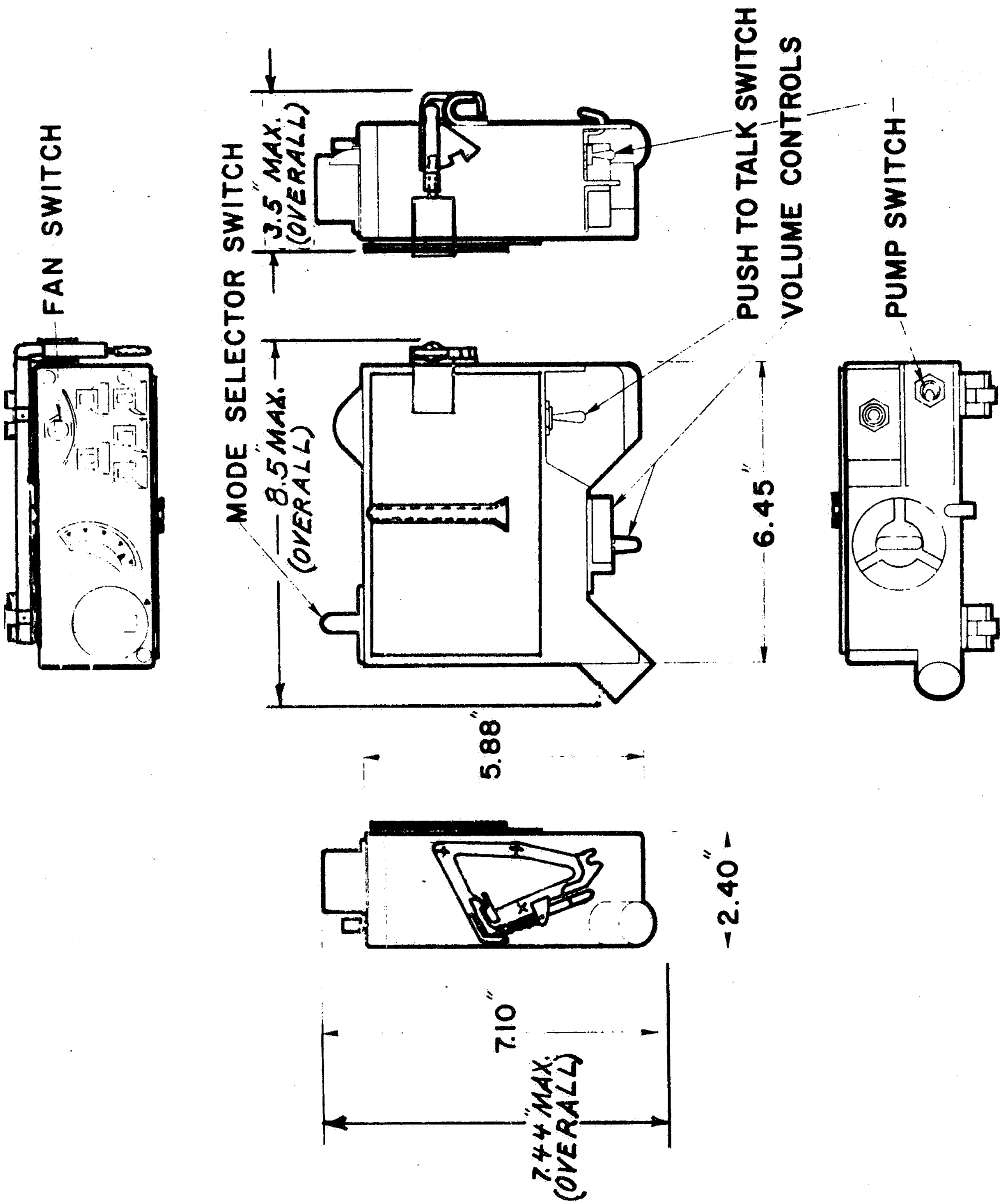


Figure 2.7-6 Remote Control Unit

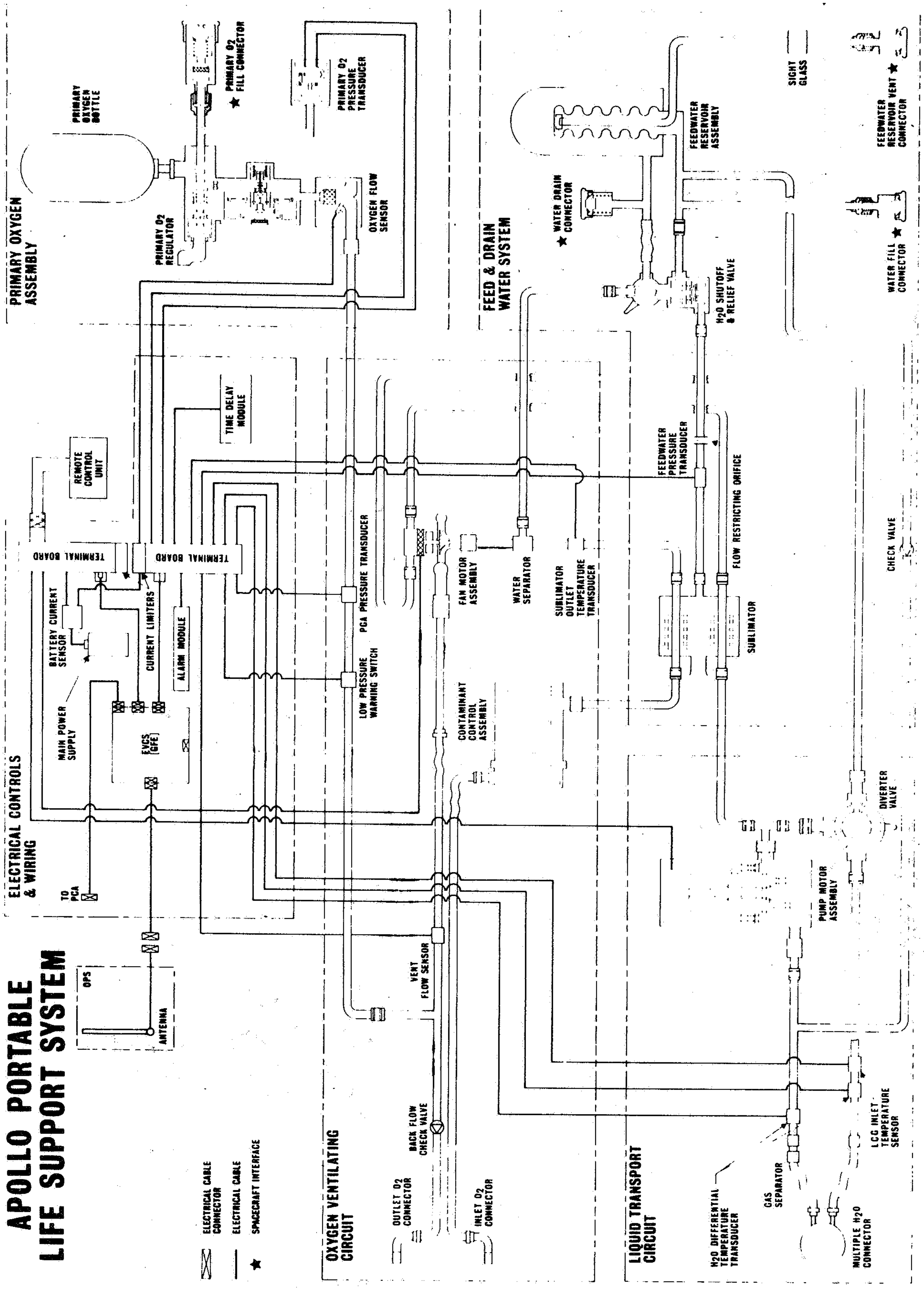


Figure 2.7-7 PLSS Functional Diagram

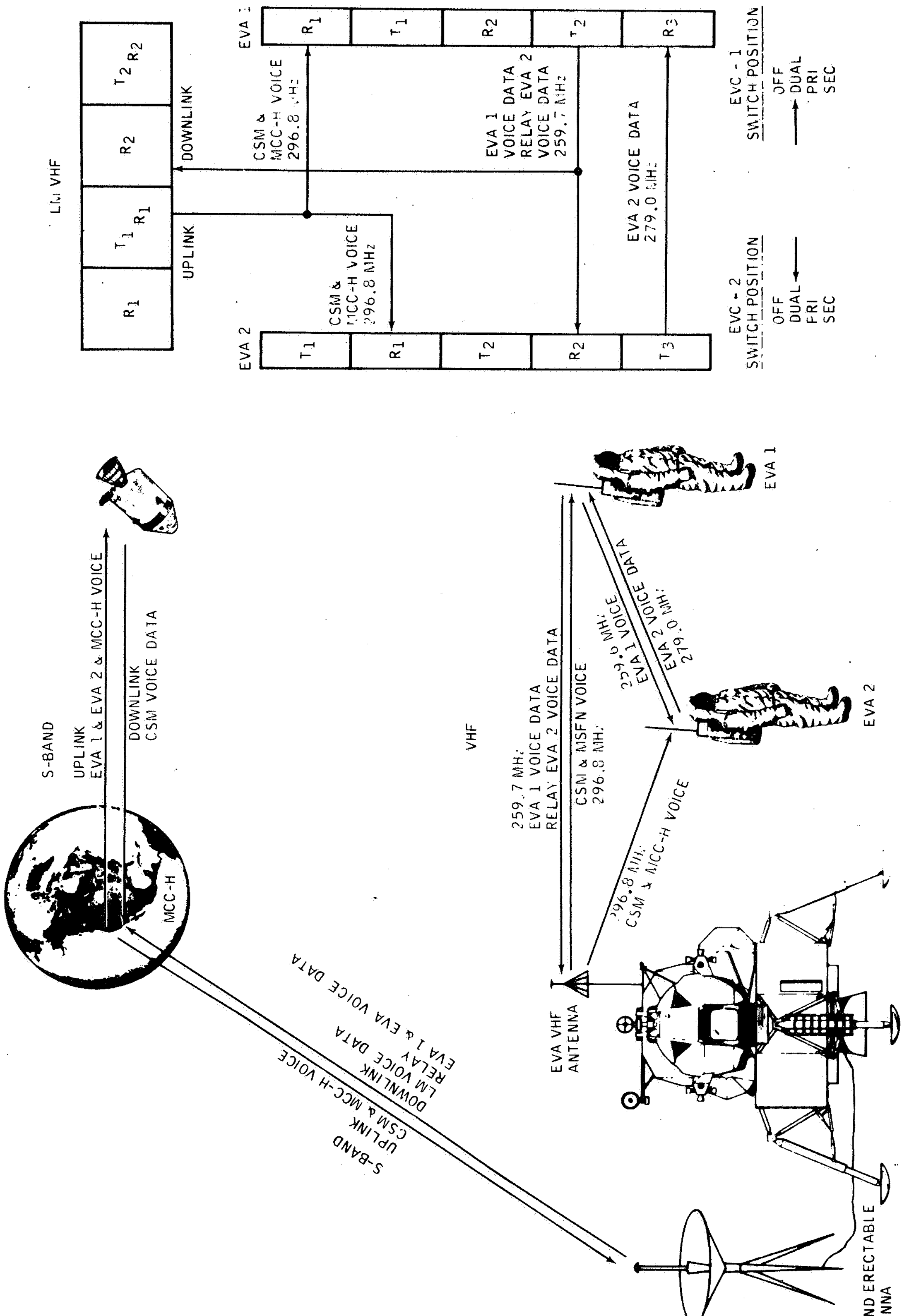


Figure 2.7-8 EVCS Pictorial Diagram: Dual-Dual

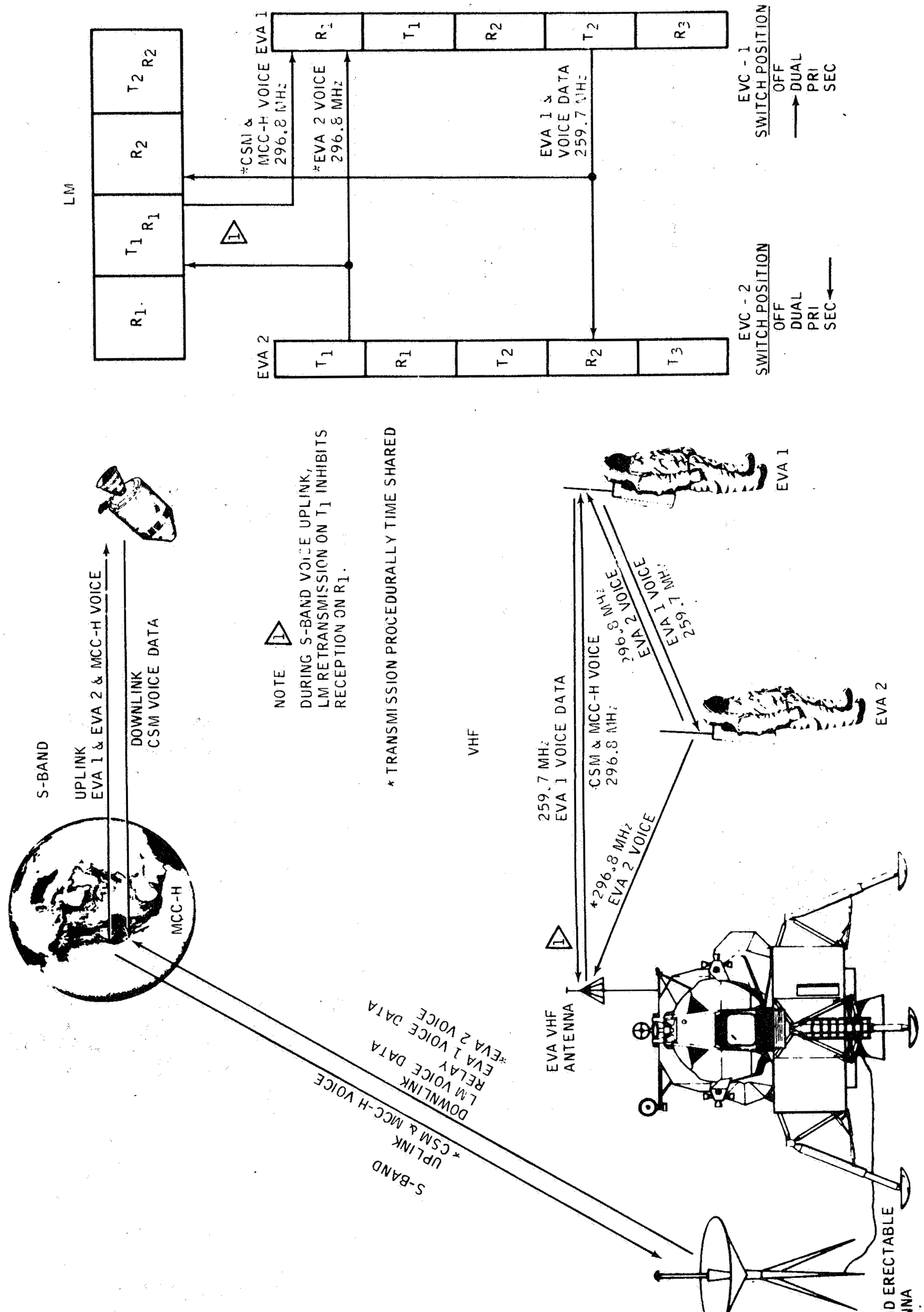


Figure 2.7-9 EVCS Pictorial Diagram: Dual-Sec

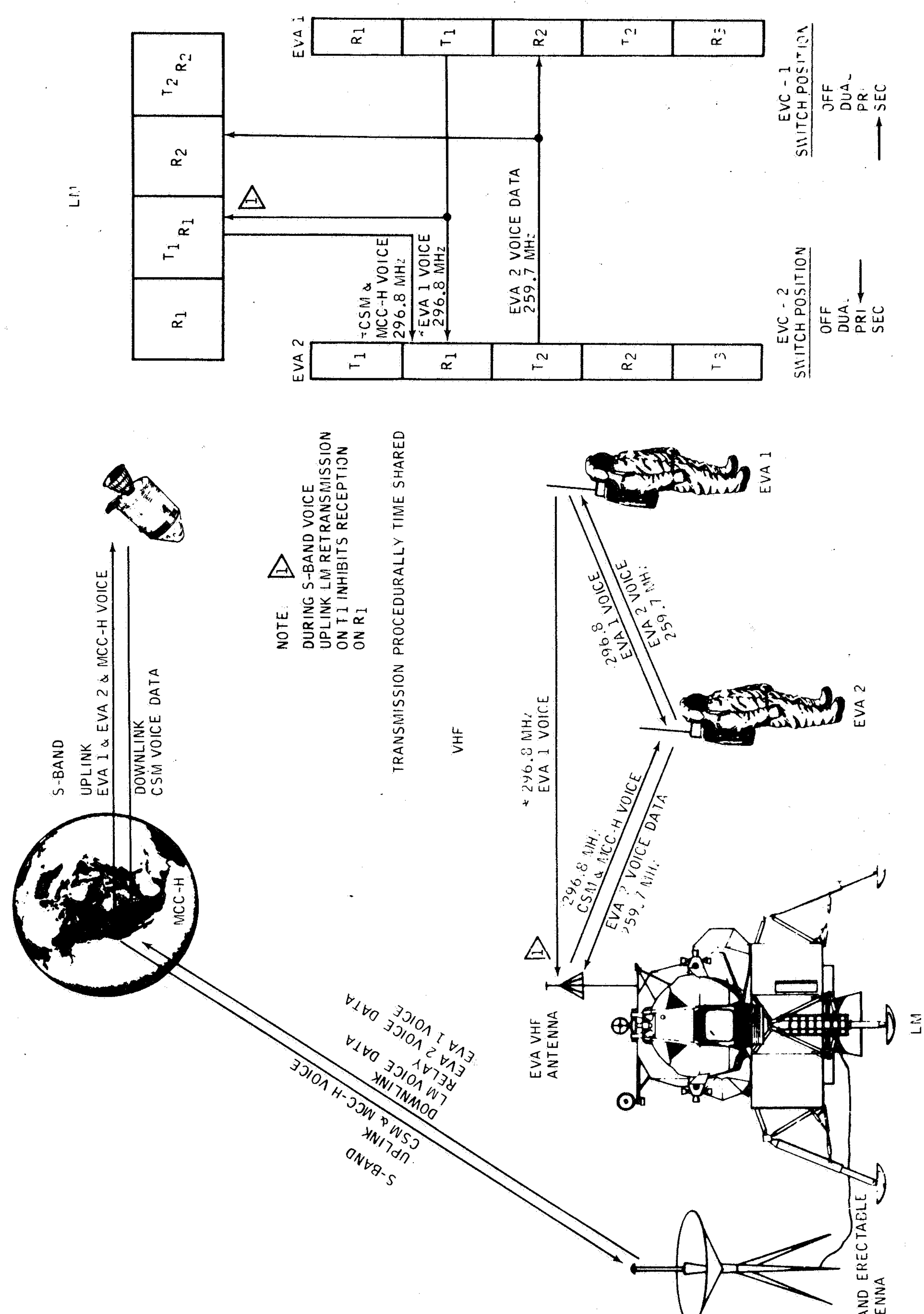


Figure 2.7-10 EVCS Pictorial Diagram: Sec-Pri

2.8 Oxygen Purge System Configuration

The OPS configuration is shown in Figure 2.8-1. The purpose of the OPS (shown schematically in Figure 2.8-2) is to perform short-term life support functions in the event of specific EMU failures. The OPS maintains a regulated pressure of 3.4 to 4.0 psia when activated during EVA. It contains two pressure bottles with a combined volume of 322 cubic inches.

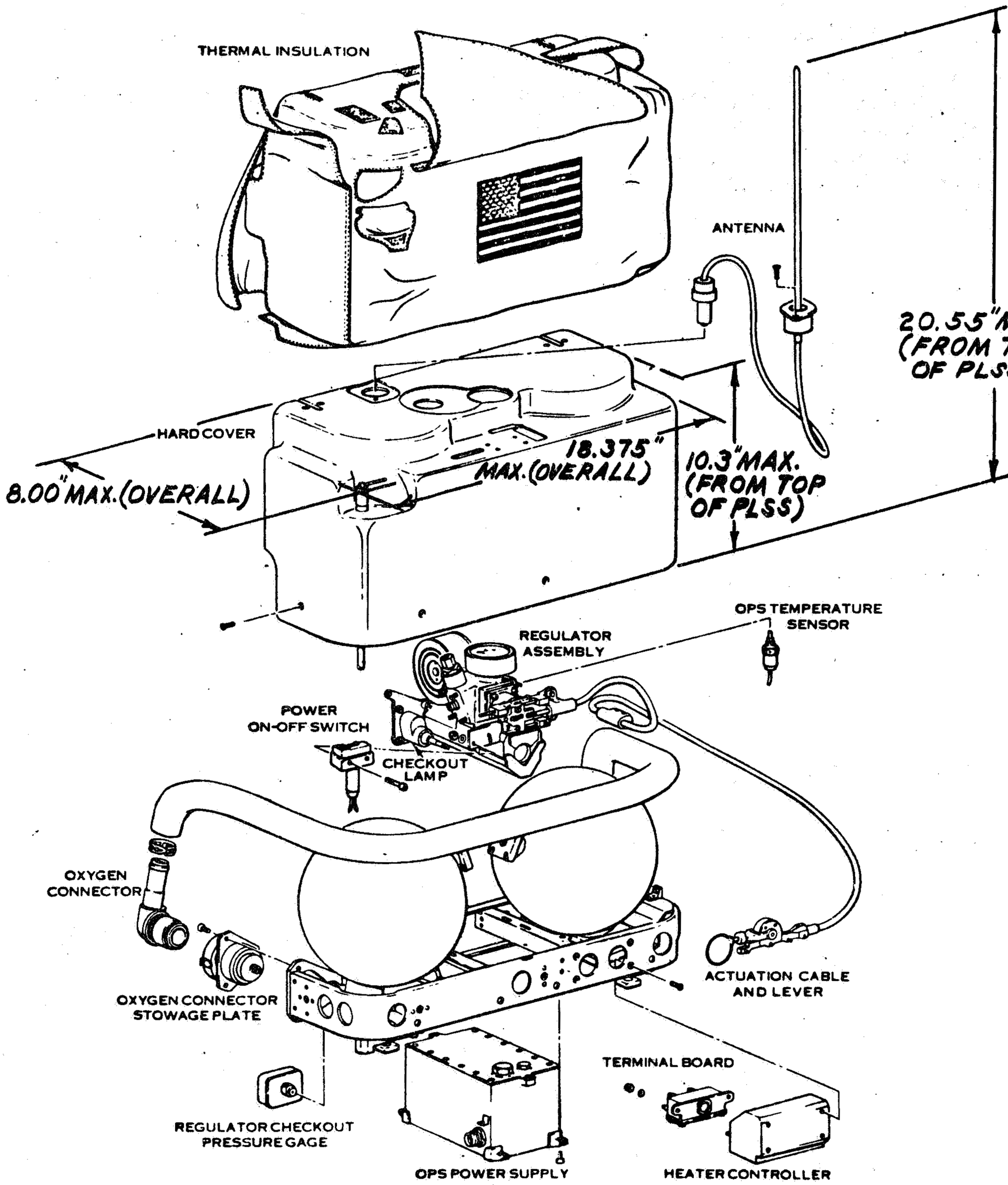
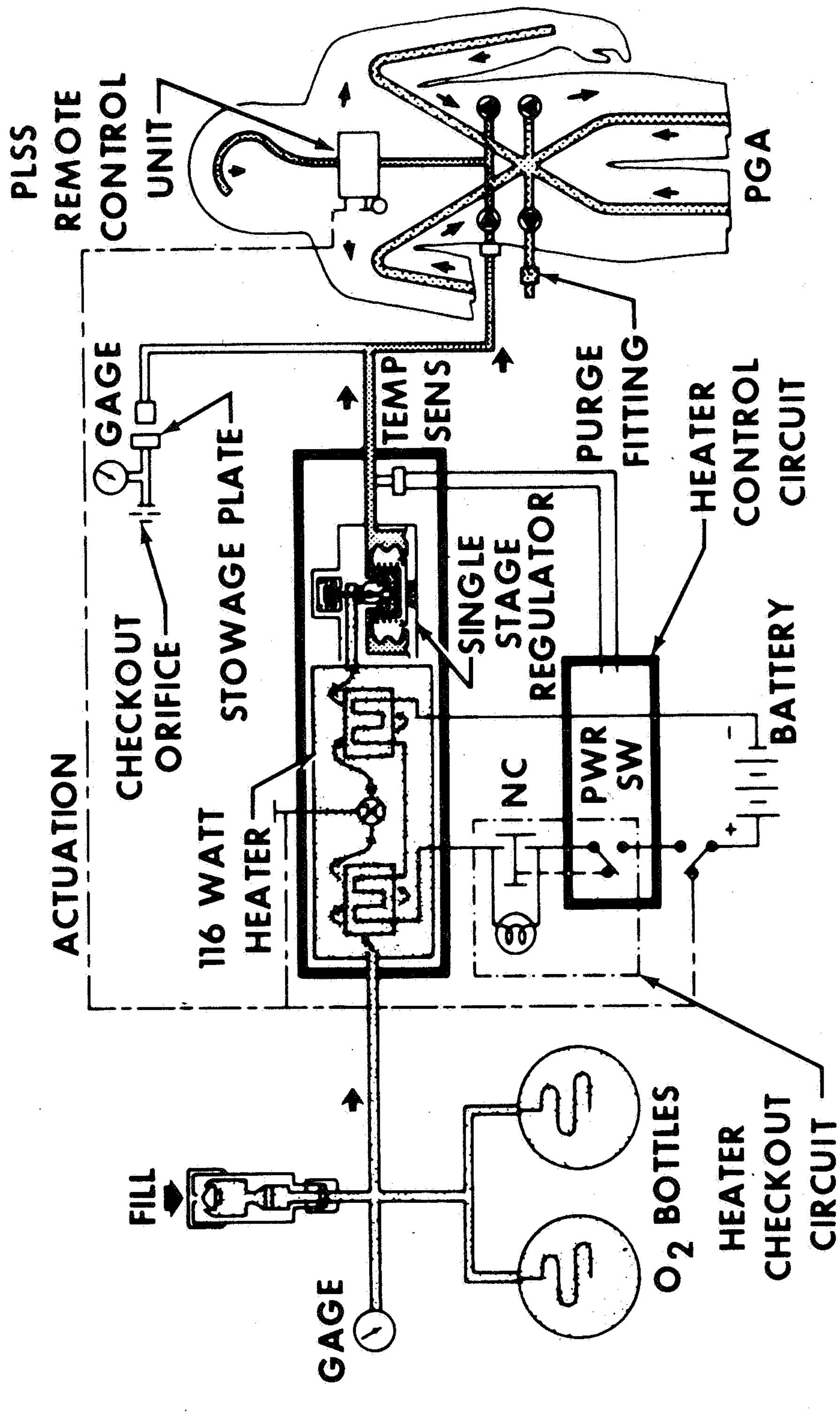


Figure 2.8-1 Oxygen Purge System - Major Components



Note: There is a filter on both sides of the shut-off valve and at the input side of the regulator.

Figure 2.8-2 Oxygen Purge System

2.9 PLSS Feedwater Collection Bag

The PLSS feedwater collection bag is capable of containing the feedwater remaining in the PLSS upon completion of lunar activity. The bag contains a connector which mates with the PLSS feedwater fill connector. After accepting the surplus feedwater, the bag maintains it in a sealed condition. The bag is designed to be used with a spring-type scale to measure the amount of feedwater collected. The weighing operation is performed in the lunar environment by a suited astronaut. Accuracy of the scale is verified by calibration with dead loads and shall be no worse than 3% of full scale in 1/6 g.

The PLSS feedwater collection bag is constructed of two layers. The inner layer is neoprene coated nylon tricot and the outer restraint layer is Nomex cloth. The bag is tubular in shape and has a hole or scale attachment point at one end and a connector which interfaces with the PLSS at the other. The bag holds approximately 5.8 lbs. of water at 1 g. The feedwater residual after draining into the feedwater collection bag is approximately 0.83 lbs.

2.9.1 Feedwater Usage Analysis

Since no direct method of measuring feedwater usage in real-time is available, the estimated computational accuracy is required. This accuracy is determined by comparing the measured feedwater remaining, using the feedwater collection bag and scale, and the calculated quantity used. The following method is used to determine the error of the calculated water usage.

a. The percent error is determined by

$$\%\ \text{Error} = \frac{\text{Actual Used} - \text{Calculated Used}}{\text{Actual Used}} \times 100$$

A positive percent error indicates that more water was actually used than the real-time calculations revealed (under estimate of the actual value), whereas a negative percent error reveals an over estimate.

b. The actual water used is determined by weighing the water after the EVA and subtracting this plus the residual from the amount loaded. The value of the residual is 0.83 lbs. If real-time circumstances reveal a sublimator dry out (e.g. early shut off of the water valve), metabolic estimations will be continued and the initial loading of a subsequent EVA will be adjusted so that no error will be attribued to the water usage after the water valve shut off.

$$\text{Actual Used} = \text{Total Loaded} - \text{Weighed} - \text{Residual}$$

2.9.1 Feedwater Usage Analysis (Continued)

c. The calculated water used is derived from the Medical Research and Operations Directorate's (MROD) assessment of metabolic rate. MROD's assessment of metabolic rate is used by FCD in conjunction with the equipment and environmental heat loads in determining an H_2O quantity usage during a given time period, and the total calculated used is equal to the total loaded minus the remaining quantity at the end of the EVA.

Calculated Used = Total Loaded - Remaining

Table 2.10-1 Unit Weights

ITEM	SPEC WEIGHT	ACTUAL WEIGHT
EV-PGA (with ITMG)	46.47 lbs	42.80 lbs
IV-PGA (with IVCL)	35.52 lbs	34.08 lbs
PLSS/EVC-1 (with O_2, H_2O, Battery, LiOH and RCU)	88.26 lbs	85.77 lbs
PLSS/EVC-2 (with O_2, H_2O, Battery, LiOH and RCU)	88.14 lbs	85.88 lbs
OPS	41.00 lbs	40.89 lbs
Lunar Boots (pair)	4.90 lbs	4.50 lbs
EV Gloves (pair)	2.50 lbs	2.15 lbs
LEVA	4.40 lbs	4.10 lbs
LCG	4.90 lbs	4.45 lbs
CWG	0.90 lbs	0.78 lbs
UCTA	0.53 lbs	0.52 lbs
FCS	0.50 lbs	0.32 lbs
Bioinstrumentation System	1.10 lbs	1.10 lbs
Communications Carrier	1.63 lbs	1.58 lbs
Feedwater Collection Bag (w/o scale)	TBD	0.47 lbs

2.11 Drinking Bag (In-Suit)

A drinking bag is provided to enable the individual crewman to have access to approximately 8 ounces of drinking water during an EVA. The bag is constructed of 10 mil. polyurethane and has a surgical rubber tube which extends into the bag and down one side to the bottom. There is a bite valve on the end of the tube exterior to the bag. The bag has a fill connector at the top on the other side which is identical to that used on the food bags. This allows the drinking bag to be refilled using the water dispenser/fire extinguisher prior to the next EVA. There is a heat seal along the vertical center line of the bag which does not extend completely to either the top or bottom, and prevents the bag from bulging excessively when it is charged. The top of the heat seal is used as an indication of a complete fill. When the water level within the bag is at the top of the heat seal, the bag contains approximately 8 ounces of water. Nylon Velcro hook and pile is incorporated along the top horizontal edge to provide for mounting the drinking bag between the comfort liner and bladder of the PGA in the chest area. The Velcro of the bag is sandwiched between that of the two suit layers at the neck opening. The drinking bag is installed in the PGA with the drinking tube on the crewman's left. To obtain water, the crewman bites gently on the mouthpiece and sucks the water as if using a straw.

3.0 OPERATIONAL CONSTRAINTS AND LIMITATIONS

3.1 Crewman/Extravehicular Activity

OPERATIONAL LIMITATIONS OR PROCEDURE	RESULTS OF EXCEEDING LIMITATION OR NOT FOLLOWING PROCEDURE
EV-1 Contingency EVA Configuration	
Minimum EMU configuration for EVA is: 1. EV-PGA 2. Pressure Helmet Assembly 3. LEVA or Helmet Shield 4. EV Gloves 5. PLSS/LCG or OPS/Purge Valve	EVA crewman safety is compromised. Insufficient to afford adequate protection
EV-2 Lunar Surface Configuration	
Minimum EMU configuration for Lunar EV is: 1. EV-PGA 2. Pressure Helmet Assembly 3. LEVA 4. EV Gloves 5. Communications Carrier 6. Lunar Boots 7. LCG 8. Bio-belt Assembly 9. Bioinstrumentation Assembly 10. PLSS/LCG and OPS/Purge Valve 11. FCS 12. UCTA	EVA crewman safety is compromised. Insufficient to afford adequate protection

Note: The PLSS, RCU, LEVA, and OPS are individually interchangeable between crewmen.

3.1 Crewman/Extravehicular Activity (Cont'd)

OPERATIONAL LIMITATIONS OR PROCEDURE	RESULTS OF EXCEEDING LIMITATION OR NOT FOLLOWING PROCEDURE
EV-3 Crewman Sweating	
The PLSS H_2O separator can handle the maximum amount of sweat picked up in the gas stream.	N/A
EV-4 Distance from LM ECS	
Crewmen EVA shall never be more than 30 minutes from connection to the LM ECS.	Possible inability of EV crewman to reach LM ECS before exhaustion of emergency O_2 supply.
EV-5 PGA Gas Diverter Valves (2)	
Gas diverter valves must be in vertical position for EVA (for either OPS or PLSS operation)	Insufficient CO_2 washout
EV-6 Crewman Carried Objects	
There is no way to describe the full range (weight, volume, shape, etc.) of objects which can successfully be carried on the lunar surface. Parameters vary with individual crewman size and capabilities.	N/A
EV-7 Reconfiguring From OPS to PLSS Operation	
When reconfiguring the EMU from OPS to PLSS operation, the purge valve shall be closed and the locking pin replaced prior to OPS oxygen shutoff.	The PGA will depressurize.

3.1 Crewman/Extravehicular Activity (Cont'd)

OPERATIONAL LIMITATION OR PROCEDURE	RESULTS OF EXCEEDING LIMITATION OR NOT FOLLOWING PROCEDURE
EV-8 Total EMU EVA Time	
The total accumulative lunar surface EVA time for the EMU shall not exceed twelve (12) hours.	Exceeds the qualified use limits presented in the CTR's for Apollo 11 hardware.
EV-9 Purge Valve Position	
The EVA pre-set position of the Purge Valve is in the LOW flow (4.0 lbs/hr) position. Use of the OPS for cooling purposes requires resetting the Purge Valve to HIGH (8.1 lbs/hr).	Time for crewman to react is not sufficient if purge valve opened to HIGH flow and OPS not actuated.
EV-10 Maximum Crewman Heat Storage	
Heat storage by crewman's body should be limited to 300 Btu.	Possible physical harm or discomfort may occur to the crewman.

3.2 Extravehicular Pressure Garment Assembly

OPERATIONAL LIMITATION OR PROCEDURE	RESULTS OF EXCEEDING LIMITATION OR NOT FOLLOWING PROCEDURE
EPG-1 Time in Uncooled PGA	
The safe maximum time allowed in an uncooled pre-egress PGA is 30 minutes.	Heat buildup in the PGA above maximum comfort point. (80°F)
NOTE: Helmet, Gloves, and PLSS O_2 are on.	
EPG-2 PGA/PLSS/OPS Pressure Integrity Checkout	
With the S/C cabin at 5.0 psia, the maximum allowable pressure decay is 0.3 psi/minute at 8.8 psia in PGA.	After extensive study and test, it is concluded that there is no way to determine in real time the leak rate of the PGA (EMU). The only purpose accomplished by a pressure integrity check is to give confidence that gross leaks are not present.
EPG-3 LEVA Visor UV Exposure	
Deleted	
EPG-4 Helmet Fogging	
The effective duration of the anti-fog compound is 6 hours: 2 hrs pre-helmet donning and 4 hrs after helmet donned.	Obstruction of the crewman's vision creating a safety hazard.

3.2 Extravehicular Pressure Garment Assembly (Cont'd)

OPERATIONAL LIMITATION OR PROCEDURE	RESULTS OF EXCEEDING LIMITATION OR NOT FOLLOWING PROCEDURE
EPG-5 Proximity to Thruster Plumes	
Only marginal protection is afforded the LEVA if its proximity to the thruster plumes is as close as 5 ft. for 0.5 seconds.	Material will be degraded (Reference GE TIR 580-S-7168)
EPG-6 Gas Connector Dust Contamination	
Excessive dust/dirt contamination of the gas connectors may prevent the locking ring to be cycled. (See EPG-7)	Crewman may not be able to reconnect O_2 umbilicals to the contaminated gas connector.
EPG-7 Connector Cleansing	
In the event of gas connector contamination, the water dispenser should be used to clean the connector. The entire operation should be loosely surrounded by a towel to minimize loose water ejected into cabin.	Loose water may be ejected into cabin.
EPG-8 EVA Glove Contact	
EVA Glove can sustain gripping of objects for 3 minutes at 250°.	Crewman hand becomes uncomfortable.
EPG-9 Unventilated PGA	
The PGA with helmet and gloves donned is limited to 60 seconds without ventilation.	CO_2 buildup in the helmet may become excessive.
EPG-10 Helmet Rotation	
Do not rotate helmet pas lock alignment marks.	Flow of oxygen to the helmet may be blocked and the neck ring seal and locking dogs may be damaged.

3.2 Extravehicular Pressure Garment Assembly (Cont'd)

OPERATIONAL LIMITATION OR PROCEDURE	RESULTS OF EXCEEDING LIMITATION OR NOT FOLLOWING PROCEDURE
EPG-11 Time in Pressurized PGA	
In order for the crewman to remain comfortable and function properly during EVA the uninterrupted time in a pressurized PGA should be limited to 8 hours.	Additional time will cause excessive fatique and discomfort and create undesireable risk
EPG-12 Helmet Crazing	
Helmet crazing does not present a pressure constraint	N/A
EPG-13 Loss of Lunar Boot	
There is no material constraint on the PGA boot; however, a potential constraint from heat leak to the crewman does exist although the onset rate will be slow. If the temperature becomes uncomfortable, then an effort should be made to don the lost boot. If this cannot be done, then abort. The PGA boot sole should be examined 5 minutes after lunar boot loss and every 15 minutes thereafter. If excessive abrasion occurs, then abort.	The temperature of the crewman's foot would exceed the comfort level. The PGA boot sole is not an integral part of the pressure envelope.
EPG-14 Cleaning and Lubrication of PGA Seals After Each EVA	
The seals of the PGA gas connectors, wrist disconnects, neck ring, and pressure sealing closure (if the closure has been actuated) shall be cleaned and lubricated after each EVA.	Sluggish operation of the connectors and disconnects during engagment and disengagment will occur.

3.3 Intravehicular Pressure Garment Assembly

OPERATIONAL LIMITATION OR PROCEDURE	RESULTS OF EXCEEDING LIMITATION OR NOT FOLLOWING PROCEDURE
IPG-1 PGA Pressure Integrity Checkout	
With the S/C cabin at 5.0 psia, the maximum allowable pressure decay is 0.3 psid/minute at 8.8 psia in PGA.	After extensive study and test, it is concluded that there is no way to determine in real time during a mission the leak rate of the PGA (EMU). The only purpose accomplished by a pressure integrity check is to give confidence that gross leaks are not present.
IPG-2 EV Exposure	
EV exposure of the IV crewman is not permitted without the LEVA or Helmet Shield. With the LEVA or Helmet Shield, exposure is limited to 30 minutes in earth orbital sunlight exposure and 20 minutes in earth shadow conditions.	Insufficient thermal protection to the crewman.
IPG-3 Helmet Shield UV Exposure	
DELETED	
IPG-4 IV Glove Contact	
The maximum temperature allowed for IV glove contact is 130°F.	130°F results in discomfort to the crewman. The bladder degrades at 160°F.
IPG-5 Time in Pressurized PGA	
DELETED	

3.4 Portable Life Support System

OPERATIONAL LIMITATION OR PROCEDURE	RESULTS OF EXCEEDING LIMITATION OR NOT FOLLOWING PROCEDURE
PLS-1 Loss of Feedwater Pressure	
The PLSS liquid transport loop will reject approximately 500 BTU of external heat after the feedwater warning tone actuates.	The temperature of the space suit environment will rise to an uncomfortable level (LCG inlet temp $80^{\circ}F$)
PLS-2 Deadhead Operation	
There is no constraint on operation of the pump or the fan deadheaded in the stowed condition.	N/A
PLS-3 Sublimator Freeze-Up	
When EV the pump should be on, and a heat load of 250 BTU/hr maintained in the liquid transport loop.	The sublimator will freeze up and the cooling function will be lost.
PLS-4 Sublimator Start-Up	
For sublimator start-up, the ambient should be 1000 microns (.02 psia) or less, and the diverter valve should be set for minimum cooling.	Sublimator breakthrough could occur on start-up.
PLS-5 Sublimator Restart	
The sublimator can be restarted at any time during the drying out process. For restart, the pressure should be 1000 microns (.02 psia) or less, and the diverter valve should be in the minimum cooling position (See PLS-4 and PLS-13).	Sublimator breakthrough could occur on restart.
PLS-6 Operation Without Cooling	
No damage will be sustained by PLSS or EVCS components by PLSS operation without cooling.	N/A

3.4 Portable Life Support System (Cont'd)

OPERATIONAL LIMITATION OR PROCEDURE	RESULTS OF EXCEEDING LIMITATION OR NOT FOLLOWING PROCEDURE
PLS-7A LM Repressurization - POS Pressure	
A minimum pressure of 200 psia is required in the primary oxygen supply to maintain the PGA in a positive pressure condition during LM repressurization.	The crewman would be required to use a slower LM repressurization to maintain positive suit pressure. (Reference Figure 4.5-53).
PLS-7B LM Repressurization - Feedwater Valve Closure	
The feedwater valve should be closed before repressurizing the LM.	Feedwater will be dumped in LM at a rate of .176 - .198 lbs/minute at a P of 3.8 psia. In any case, .288 to .331 pounds of water will be dumped upon subsequent LM Depress.
PLS-8 Fan and Pump Switch Off	
Deleted.	
PLS-9 LiOH Exposure to Vacuum	
The LiOH Cartridge should not be exposed to an ambient pressure less than 0.5 psia for more than 15 minutes. (The stowed cartridge is sealed to the S/C environment).	Exposure to an ambient pressure less than 0.5 psia causes the water in the LiOH to vaporize limiting its use time in the EMU to 60 minutes maximum.
PLS-10 Diverter Position After Start-Up	
The diverter valve can safely be placed in the desired cooling position 5 minutes after start-up in the event the pressure transducer fails and causes erroneous indications (see PLS-4 and PLS-5).	Sublimator breakthrough could occur.

3.4 Portable Life Support System (Cont'd)

OPERATIONAL LIMITATION OR PROCEDURE	RESULTS OF EXCEEDING LIMITATION OR NOT FOLLOWING PROCEDURE
PLS-11 POS Use After Recharge	
There are no constraints on the use of the primary oxygen supply after recharge.	N/A
PLS-12 POS Contamination	
There is no minimum pressure required to prevent back flow contamination of the primary oxygen supply. A filter prevents contamination.	N/A
PLS-13 Sublimator Breakthrough	
If breakthrough occurs, these steps must be followed in order to accomplish restart: 1. Close feedwater valve. 2. Place diverter valve in max. cooling position. 3. Maintain activity for at least 5 minutes to facilitate sublimator dryout. (See Notes 1 & 2) 4. Place diverter valve in min. cooling position. 5. Open feedwater valve. 6. Desired diverter valve position may be selected when feedwater pressure is acquired indicating successful startup. (Approx. 5 minutes - see PLS-10).	Startup will not occur. NOTE 1: The most recent flight data indicative of a wet sublimator restart shows that sublimator dry-out is not required for a successful restart for operation with low sublimator heat loads. A hot restart (high sublimator heat loads) will require sublimator dryout. NOTE 2: An indication of sublimator dryout is the decay of feedwater pressure below the vapor pressure of water (0.5-0.7 psia).
PLS-14 Pump Shutdown	
Pump shutdown while EVA shall be limited to 10 minutes maximum. Pump shutdown while inside the unpressurized LM is also 10 minutes.	Liquid transport water in sublimator will freeze rendering the liquid transport loop inoperable.

3.4 Portable Life Support System (Cont'd)

OPERATIONAL LIMITATION OR PROCEDURE	RESULTS OF EXCEEDING LIMITATION OR NOT FOLLOWING PROCEDURE
PLS-15 Diverter Valve Positioning	
Diverter valve positioning between detents does not shut off the transport water loop. Portions of each position will allow some flow.	N/A
PLS-16 Battery Storage	
The battery shall be stored within the temperature limits of $0^{\circ}F$ to $130^{\circ}F$. Plate warpage will occur at $160^{\circ}F$.	Possible degradation of battery performance. Definite degredation if plate warpage occurs.

3.4 Portable Life Support System (Cont'd)

OPERATIONAL LIMITATION OR PROCEDURE	RESULTS OF EXCEEDING LIMITATION OR NOT FOLLOWING PROCEDURE
PLS-17 LiOH Storage Temp	
The LiOH Cartridge can be stored at temperatures within limits of figure 4.5-34, page 4.5-40.	Reduced LiOH efficiency.
PLS-18 LM ECS/PLSS Hybrid	
Constraints associated with the following LM/ECS Hybrids:	
(a) Static PLSS oxygen ventilation loop. PLSS gas connectors must be connected to the PGA or the PLSS oxygen valve must be on.	Water will not be expelled to the Sublimator.
(b) Static PLSS liquid transport loop. (LTL) (Ref. PLS-14) Pump shutdown is limited to 10 minutes.	Sublimator freeze up may damage sublimator and preclude subsequent restart. No damage is expected to the O_2 loop.
(c) Static PLSS LTL and Sublimator. Eventual helmet fogging dependent on the metabolic load.	Loss of visibility through the helmet.
PLS-19 Feedwater Collection	
The feedwater shall not be collected with the feedwater collection bag if the feedwater remaining is greater than 5.8 pounds.	Exceeds the feedwater collection bag capacity.

.4 Portable Life Support System (Cont'd)

OPERATIONAL LIMITATION OR PROCEDURE	RESULTS OF EXCEEDING LIMITATION OR NOT FOLLOWING PROCEDURE
PLS-20 Contingency Retention of PLSS	
In the event both PLSS's are retained to satisfy contingency EVA requirements, the following procedures must be followed: (a) All connector caps shall be in place. (b) All umbilicals (including the battery cable) shall be in their respective stowage plates. (c) The LiOH Cartridge shall be removed from the PLSS and stowed in any bag where space is available.	Vital connectors and/or umbilicals could be damaged precluding their use. The LiOH could be degraded by residual moisture in the PLSS and rendered useless.
PLS-21 Feedwater Replenish Temperature	
The maximum temperature of water for feedwater replenish shall be 109°F.	Excess feedwater temperature will cause sublimator breakthrough.
PLS-22 Diverter Valve Position After Start-up	
When the low feedwater pressure warning flag clears the diverter valve may be placed in any desired position.	Earlier diverter valve positioning will cause sublimator breakthrough.
PLS-23 Gas Separator EVA Bleed	
There is no freezing constraint associated with the contingency bleeding of the gas separator during EVA.	N/A

3.4 Portable Life Support System (Cont'd)

OPERATIONAL LIMITATION OR PROCEDURE	RESULTS OF EXCEEDING LIMITATION OR NOT FOLLOWING PROCEDURE
PLS-24 Use of LM Urine Bags During Recharge	
The LM urine bags shall not be used as a receptacle for the PLSS condensate during a feedwater recharge.	The condensate side of the bladder in the feedwater reservoir has an approximate volume of 4400 cc's which includes 875 cc's of condensate after a nominal mission. The urine bags have an approximate volume of 875 cc's. Since the feedwater is recharged to a pressure of 40 psi, which is the pressure forcing the condensate plus air into the urine bags, and since the urine bags are only proof pressurized to 10 psi, the consequence of attempting this operation would result in an exploded urine bag.
PLS-25 Thermal Load on Sublimator	
A maximum thermal load at the sublimator of 8750 BTU/Hr. should not be exceeded.	Sublimator breakthrough will occur.

3.5 Oxygen Purge System

OPERATIONAL LIMITATION OR PROCEDURE	RESULTS OF EXCEEDING LIMITATION OR NOT FOLLOWING PROCEDURE
OPS-1 OPS Charge	
The pressure of the OPS shall not exceed 6950 psia.	The regulator performance becomes erratic
OPS-2 OPS Actuation	
The OPS hose shall be securely connected to its stowage plate, PGA, or held by the crewman before actuating the OPS.	The thrust developed is sufficent to cause damage.
OPS-3 OPS Heat Removal	
The OPS is capable of heat removal at the rate of 600 to 800 BTU/hour. This limit is the result of the purge valve restricting flow.	The Astronaut becomes overheated.
OPS-4 OPS Unrestrained Flow	
The OPS will empty all usable oxygen in 4.2 minutes when the flow is unrestrained.	N/A
OPS -5 OPS Electrical Checkout	
Successful electrical checkout is not mandatory for manned operations	Crewman can tolerate temperatures of the gas with heater not operating

3.5 Oxygen Purge System (Cont'd)

OPERATIONAL LIMITATION OR PROCEDURE	RESULTS OF EXCEEDING LIMITATION OR NOT FOLLOWING PROCEDURE
<u>OPS-6 Intermittent Use of OPS</u>	
If the OPS is to be used temporarily to correct some minor difficulty such as helmet fogging, the PLSS O_2 shut-off valve must be turned off prior to actuating the OPS.	Because of the set points of the two regulators, the POS regulator will attempt to supply the 8.0 lbs/hr allowed by the purge valve. The OPS will supply only the difference. This will deplete the POS supply rapidly to a point severely restricting the mission profile and/or requiring a recharge of the PLSS O_2.

3.6 Extravehicular Communications System

OPERATIONAL LIMITATION OR PROCEDURE	RESULTS OF EXCEEDING LIMITATION OR NOT FOLLOWING PROCEDURE
EVCS-1 Line of Sight	
RF line of sight must exist between transmitting and receiving antenna for all communication.	Complete loss of communications.
EVCS-2 LM-MSFN-CSM Relay	
While communicating with the CSM via the LM and MSFN relay, the EVA crew must allow 4.8 to 6.0 seconds for each reply. In communicating with MSC, 2.4 to 3.0 seconds must be allowed.	Lack of discipline results in loss of intelligent communication between the EV crewman, the CSM, and MSC.
EVCS-3 Proximity to LM VHF Antenna	
There is no constraint as to nearness to the LM VHF antenna.	N/A
EVCS-4 Range	
The range is limited to one mile between LM and EVC-1 (CDR) and one-half mile between Astronauts.	Probable loss of communications.
EVCS-5 Operation in LM	
The EVCS is unrestricted for operation within the LM. (See EVCS-7)	N/A
EVCS-6 Operation Without Antenna	
The EVCS should not be operated without the antenna.	Although the EVC's are capable of operating for four hours with the antenna terminals shorted or open, communication will be lost for the duration of the anomaly.

3.6 Extravehicular Communication System (Cont'd)

OPERATIONAL LIMITATION OR PROCEDURE	RESULTS OF EXCEEDING LIMITATION OR NOT FOLLOWING PROCEDURE
EVCS-7 Antenna Stowed	
EVCS operation with the antenna stowed is an out of spec condition, and is an individual characteristic of each individual unit.	Possible loss of power and/or excessive voice distortion. If severe distortion encountered go to operationally unstowed mode.
EVCS-8 Mode Selection	
The two EV communicators should never be in the Primary (A) or Secondary (B) modes simultaneously.	The frequencies will beat and a loud interfering signal will be produced.
EVCS-9 Mode Restriction on EVC-2	
The EVC-2 communicator shall be switched to Primary (A) or Secondary (B) mode if and when the EVC-1 communicator is switched from the Dual (AR) mode. (Reference EVCS-8 above).	All communication from the EVC - 2 communicator will be lost.
EVCS-10 Proximity to Erectable S-Band Antenna	
The crewman shall not get directly in front of S-Band antenna in the radiating path. No other constraint exists.	Getting in front of antenna sufficient to be dangerous would be very difficult. Touching from back-side would cause only slight temperary static.
EVCS-11 Failed EVA Antenna	
With the EVA antenna failed transmission between crewman and LM inline with the fore or aft VHF inflight antenna is estimated to be limited to one-half mile.	Probable loss of communications with crewman.

4.0 SUBSYSTEM PERFORMANCE DATA

This section presents data concerning the performance of EMU subsystems. The initial data presented is that which is applicable to the system as a whole. The ensuing paragraphs provide data of increased detail on the operating characteristics of the individual subsystems.

The EMU subsystems design/operational limits are provided in Table 4.0-1 and the proof and burst pressures of these subsystems are provided in Table 4.0-2. The EMU consumables management information is shown in Table 4.0-3. The EMU heat leak as a function of the sum angle is shown in Figure 4.0-1.

Table 4.0-1 EMU Subsystems Design/Operational Limits

SUBSYSTEM	VOLUME	TEMPERATURE		PRESSURE		LEAKAGE RATE	VOLTAGE
		MAXIMUM	MINIMUM	MAXIMUM	MINIMUM		
PORTABLE LIFE SUPPORT SYSTEM							
Primary Oxygen	378 -384 in^3	110°F	35°F	1110 psia	100 psia	3 scc/min @ 1020 + 10 psia	----
Feedwater	.135 - .143 ft^3	109°F	35°F	3.7 psia	1.6 psia	1.64 cc/hr	----
Power Supply	----	160°F	0°F	----	----	----	16.0 - 17.[illegible] VDC
Vent Loop	0.214 ft^3	110°F	35°F	4.05 psia	3.5 psia	17 scc/min	----
Transport Water	0.020 ft^3	90°F	35°F	44 psia	3.5 psia	0.27 cc/hr	----
OXYGEN PURGE SYSTEM							
Oxygen Supply	320 in^3	+130°F*	-60°F*	6750 psia	500 psia-100 psia (make-up mode)	20 scc/hr	----
Power Supply	----	160°F	0°F	----	----	----	25.2 - 28.0 VDC
Low Pressure Vent System	----	80°F	30°F	4.0 psia	3.4 psia	3 scc/min	----
PRESSURE GARMENT ASSEMBLY							
EV - PGA (total)	0.75 to 2.2 ft^3	250°F	-290°F	5.5 psig	3.5 psig	180 scc/min	----
Torso Limb Suit	----	----	----	----	----	145 scc/min	----
Helmet	----	----	----	----	----	15 scc/min	----
EV Gloves (each)	----	----	----	----	----	10 scc/min	----
IV Gloves (each)	----	----	----	----	----	10 scc/min	----

* FAILED HEATER -on and off- NORMAL PURGE FLOW

Table 4.0-2 EMU Proof and Burst Pressures

SYSTEM	PROOF PRESSURE	BURST PRESSURE
PLSS		
Primary Oxygen	1665 psid	2220 psid
Feedwater	75 psid	100 psid
Vent Loop	9 psid	12 psid
Transport Water	75 psid	100 psid
OPS		
Oxygen Supply	10,130 psid	13,500 psid
Low Pressure Loop	6 psid	8 psid
PGA		
Pressure Garment Assembly*	8 psid	10 psid

* THE PGA HAS A STRUCTURAL PRESSURE OF 6 psid.

Table 4.0-3 EMU Consumables

	PRIMARY OXYGEN PLSS ITEM	FEEDWATER RESERVOIR	LIQUID TRANSPORT LOOP	LIQUID COOLING GARMENT (LCG)	OPS O_2 BOTTLES	PLSS LiOH CARTRIDGE	PLSS BATTERY	OPS BATTERY
Volume (ft^3)	0.219	0.139	0.02	N/A	0.185	N/A	N/A	N/A
Nominal Loading	1.257 lbs at 1020 psia, 70°F	8.55 lbs (6)	1.25#	0.77 lbs	5.82 lbs at 5880 psia, 70°F	3.0 lbs	16.5 amp hr at 16.8 VDC	2.6 amp hr at 27.0 VDC
Loading Inaccuracy	0.013 lbs at ± 10 psia, 70°F	.06 lbs	± 0.06#	N/A	.080 lbs at 80 psia, 70°F	N/A	N/A	N/A
Charged Stowage Lifetime	N/A	14 days	14 days	14 days	N/A	N/A	12 days	24 days
Leak Rate	3 scc/min at 1020 ± 10 psia	1.64 cc/hr at 50 psig	0.27 cc/hr at 25.5 psig	N/A	20 scc/hr at 6935 + 200 psig	N/A	N/A	N/A
Leakage Over 200-hr Period	0.101 lbs	0.13	N/A (1)	N/A	0.0117 lbs	N/A	N/A	N/A
Residual	0.123 lbs at 100 psia, 70°F	0.78 to 0.95 lbs (2)	N/A	N/A	500 psia - Purge 0.521 lbs, 70°F 0.642 lbs, -30°F 100 psia - Makeup 0.106 lbs, 70°F	Minimum 34% reaction efficiency	N/A	N/A
TM Inaccuracy	0.035 lbs at ± 28 psia, 70°F	N/A	N/A	N/A	N/A	N/A	0.75 amp hr at 5 hrs (5)	N/A
O/B Inaccuracy (3)	0.0615 lbs at ± 50 psia, 70°F	N/A	N/A	N/A	0.313 lbs at 300 psia, 70°F	N/A	N/A	N/A
TM Usable	0.964 lbs	N/A	N/A	N/A	N/A	N/A	15.75 amp hr	N/A
O/B Usable	0.937 lbs	*7.47-7.64	*1.25 lbs	*0.77 lbs	5.29 lbs	*4800 BTU	N/A	*2.6 amp hr

*No method of consumable readout. Usable is loading less residual and leakage.

1. Leakage is part of 0.13 lbs. total leakage shown as feedwater reservoir leakage.
2. Residual includes quantity of water that fills sublimator in addition to reservoir expulsion inefficiency.
3. O/B denotes onboard readout accuracy.
4. 200 scc/min = 0.035 lb/hr O_2 and represents maximum specification EMU leakage.
5. Based upon 0.15 AMP/HR.
6. Subsequent to the first EVA the total loading of the recharged feedwater reservoir is 0.3 lbs in addition to that reported at pre-launch PIA. This addition represents H_2O trapped between the S/O valve and the sublimator.

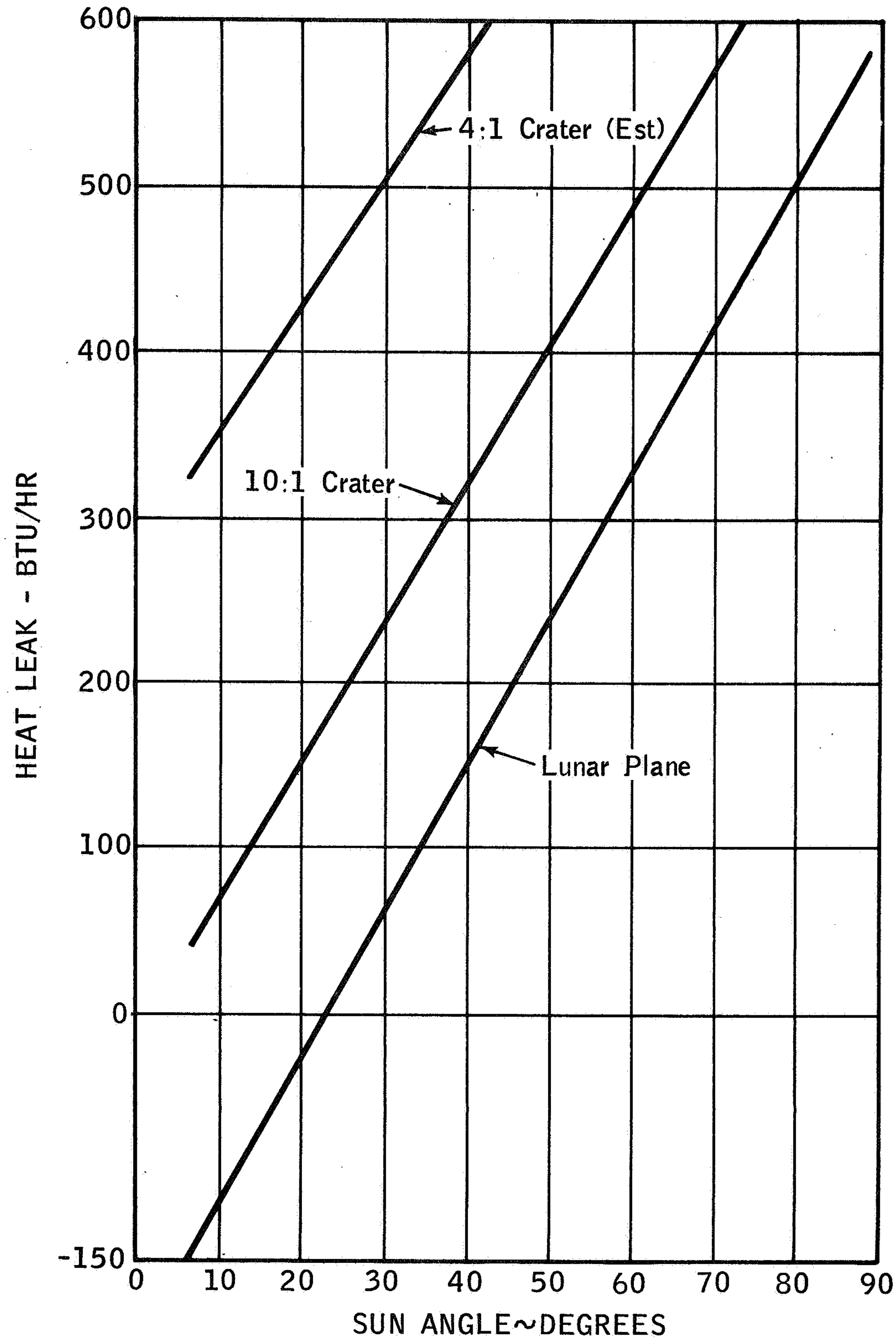


Figure 4.0-1 EMU Heat Leak versus Sun Angle

4.1 Pressure Garment Assembly

The PGA consists of a pressure helmet, torso limb suit, intravehicular gloves, an external coverlayer, and various controls and instrumentation. The garment is designed to be worn for 115 hours at a regulated pressure of 3.85 ± 0.15 psid in conjunction with either the LCG or the CWG.

Two configurations of the PGA are to be flown on all Apollo missions. In the intravehicular configuration, which is worn by the Command Module Pilot (CMP), the basic torso limb suit is covered by a fire and abrasion resistant coverlayer. Redundant gas connectors and other extravehicular components have been removed to decrease weight and bulk. In the extravehicular configuration, an integrated thermal micrometeroid garment (ITMG) is attached to the PGA for protection against thermal loads and micrometeroid penetration, in addition to fire and abrasion protection. The weight and other leading particulars are given in Table 4.1-1.

4.1.1 PGA Internal Volume

Because the internal volume of the PGA varies with the size of the crewman for whom it is constructed, the internal volume is considered to be 4.7 cubic feet ± 10%. Because the free volume (manned) varies also with the fit of suit to the crewman, the free volume is considered to be 2.2 cubic feet ± 5%.

4.1.2 PGA Orifice Flow Rates

The PGA Pressure Relief Valve flow characteristics as a function of the PGA pressure is shown in Figure 4.1-1. The flow characteristics of the PGA Pressure Transducer porous plug as a function of the PGA pressure is shown in Figure 4.1-2.

Table 4.1-1 PGA Performance Characteristics

ITEM	VALUE IV-PGA	EV-PGA
Temperature Limitation	S/C Wall -20 to + 150°F	± 250°F
Leak Rate (Max) at 3.7 psid	180 scc/min.	180 scc/min.
Operating Pressure	3.75 ± .25 psid	3.75 ± .25 psid
Pressure Drop		
12 acfm, 3.9 psia, 50°F, inlet diverter valve in IV position.	4.70 in. H_2O	4.70 in. H_2O
6 acfm, 3.9 psia, 50°F, inlet diverter valve in EV position.		1.80 in. H_2O
Pressure Relief Valve Flow Rate	3.6 + .2 lbs/hr. @ 5.$\overline{5}$ psia	3.6 + .2 lbs/hr. @ 5.$\overline{5}$ psia
Weight	34.13 lbs.	43.42 lbs.

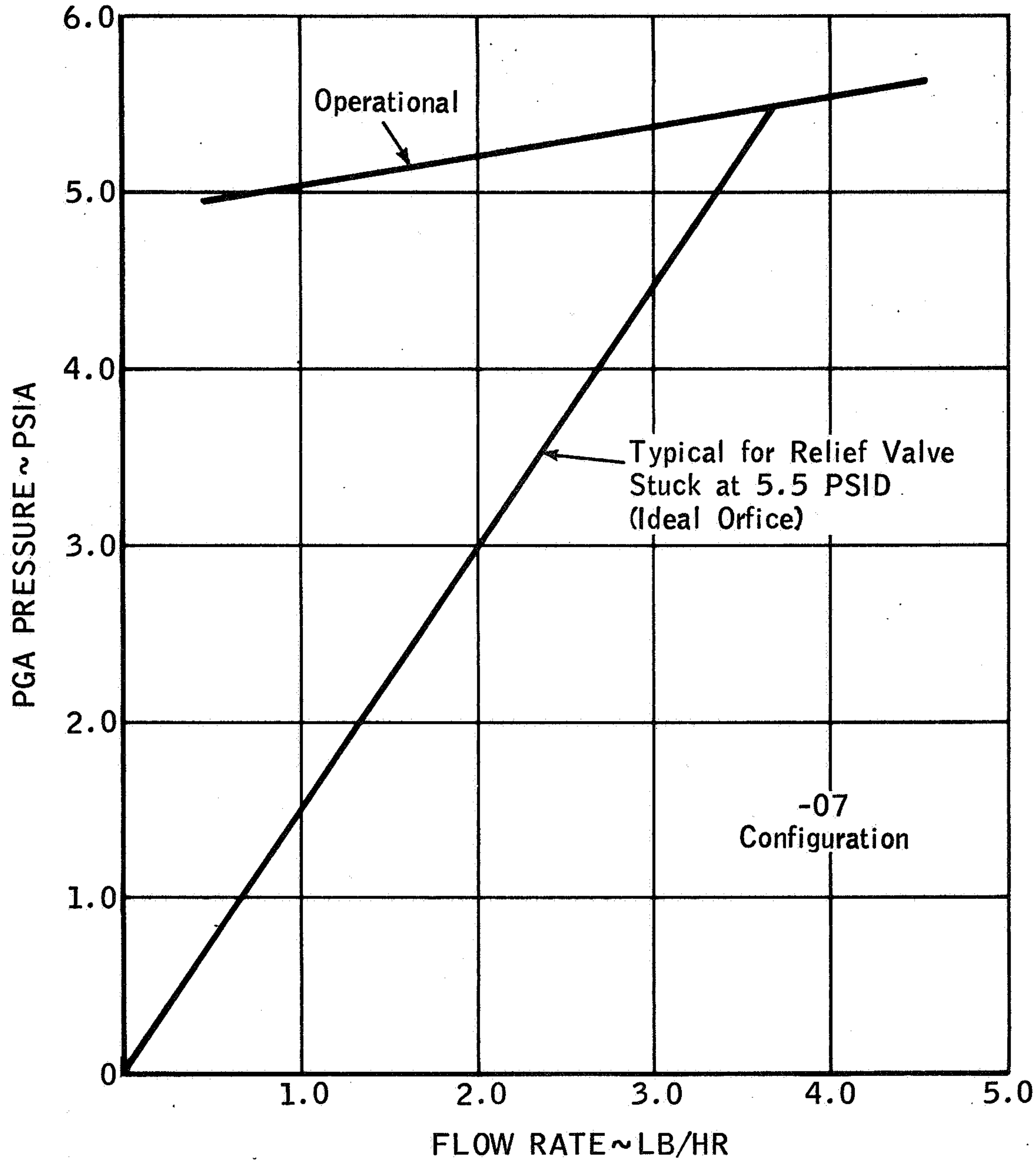


Figure 4.1-1 PGA Relief Valve Flow Characteristics

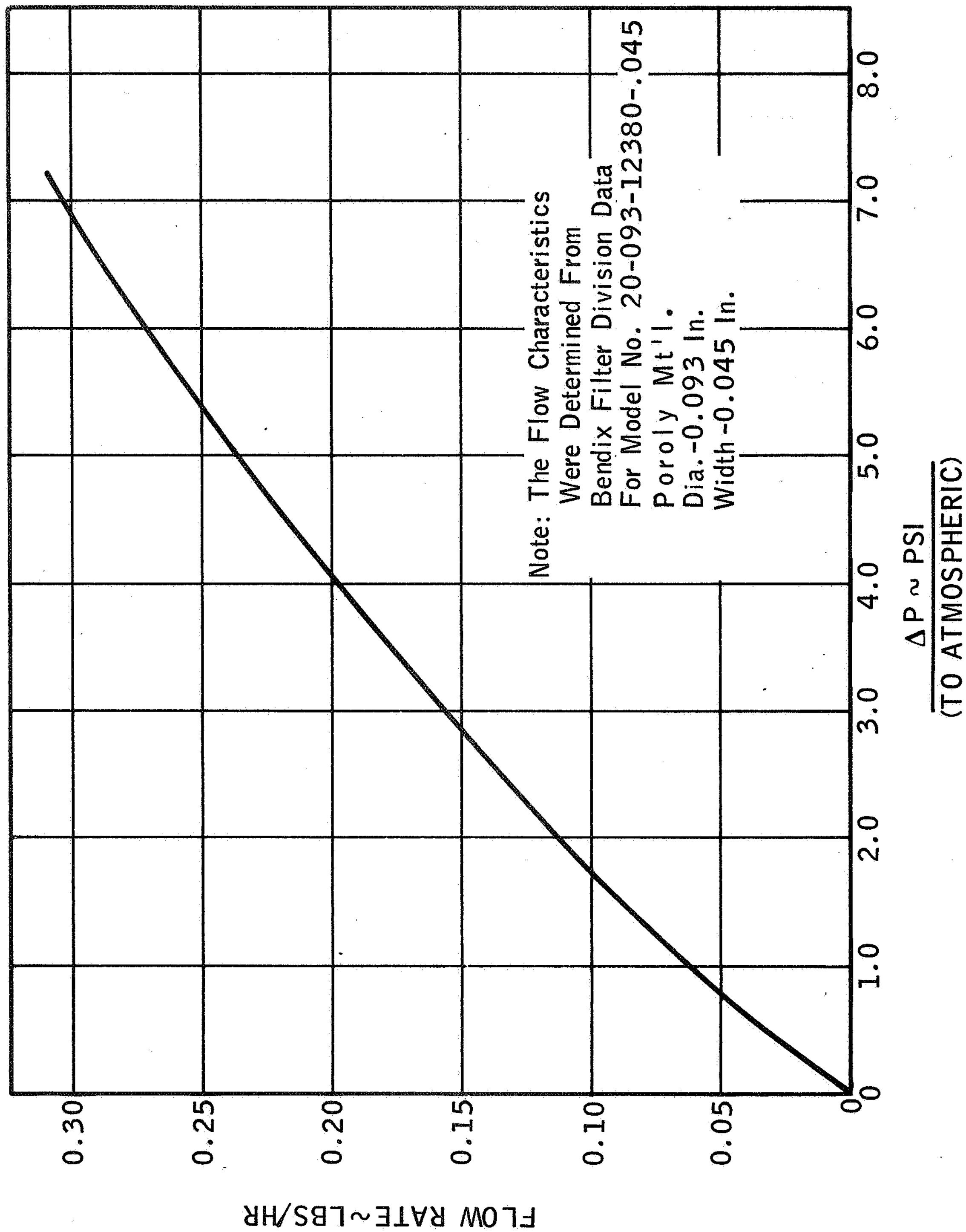


Figure 4.1-2 PGA Pressure Transducer - Low Pressure Transducer Porous Plug Flow Characteristics

4.2 LCG

The LCG is worn next to the skin under the PGA during LM and EV activities. The LCG is made of nylon-spandex knitted material, and provides for general comfort, perspiration absorption, and thermal transfer between the crewman's body and the garment's cooling media. The garment provides a continuous flow of temperature controlled water through a network of polyvinyl chloride (PVC) tubing stitched to the inside surface of the open mesh fabric garment. A lightweight nylon comfort liner separates the body from the tubing network.

The LCG can remove heat at a maximum rate of 2000 BTU/hr. for 15 minute periods, or a continuous rate of 1700 BTU/hrr. (These parameters are dependent upon PLSS operational design). Leading particulars of the LCG are given in Table 4.2-1.

4.2.1 LCG Pressure rofile

The LCG pressure profile in the various environments is as follows:

a. Sea level charge pressure is 28.5 psia.
b. While stowed in the CM, the LCG is in a bag evacuated to 2.85-5.0 psia. Based on test results, measurable loss in LCG weight or gas permeation into the LCG does not occur.
c. Operating pressure in LM is 12-21 psig above cabin ambient of 5 psia.
d. Operating pressure on lunar surface is 4 to 21 psia in 3.8 psia suit environment.

A typical LCG pressure profile prior to LCG/PLSS interfacing is depicted in Figure 4.2-1.

4.2.2 LCG Internal Volume

The internal volume of the LCG tubing nominally is 350 cc. The range is approximately 310 - 380 cc.

Table 4.2-1 LCG Performance Characteristics

ITEM	VALUE
Weight (Charged)	[a]4.60 lbs.
Operating Pressure	4.2 to 23.0 psid
Pressure Drop	
4.0 lbs/min. flow at $70^{\circ} \pm 10^{\circ}F$ inlet temp.	3.2 psi including both halves of connector
Leak Rate (Maximum)	
19.0 psid pressure differential @ $45^{\circ}F$	0.58 cc/hr.

[a]Design Value

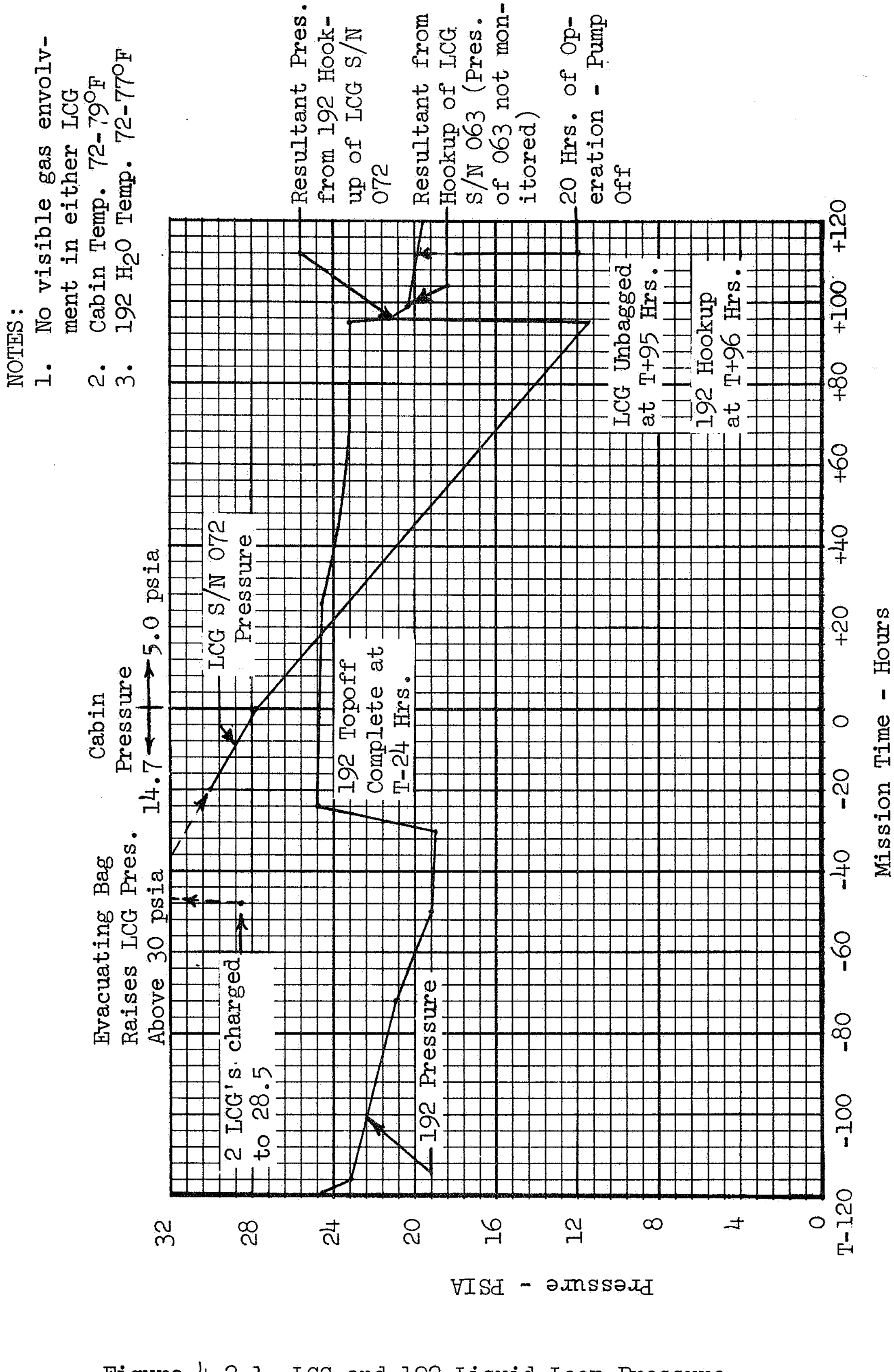


Figure 4.2-1 LCG and 192 Liquid Loop Pressure Vs. Mission Time

4.3 Urine Collection and Transfer Assembly (UCTA)

The UCTA collects and provides intermediate storage of a crewman's urine during launch, EVA, or emergency modes when the spacecraft waste management system cannot be used. The UCTA will accept urine at rates up to 30 cc/sec with a maximum stored volume of 950 cc. No manual adjustment or operation by the crewman is required while the UCTA is collecting urine. Pressure relief valves are incorporated in the urine collection bag to prevent exposure of the penis to pressure differentials of $\pm$ 1 inch H_2O between the collection bag and the PGA. The valves open automatically as required to increase pressure within the collection bag. A flapper check valve prevents reverse flow from the collection bag to the urinal portion of the UCTA. The stored urine can be transferred through the suit wall by hose when feasible to the CM or LM during both pressurized and depressurized cabin operation.

The UCTA is worn over the CWG or the LCG, and is connected by hose to the urine transfer connector on the PGA. This urine transfer connector is a quick-disconnect fitting which is used for the transfer or urine from the UCTA to the spacecraft waste management system.

4.4 Bioinstrumentation System (BIS)

The bioinstrumentation system is attached to either the CWG or LCG, and contains the necessary bioinstrumentation for crew status check. The bioinstrumentation, connected to the PGA electrical harness, consists of an EKG signal conditioner, impedance pneumograph (ZPN) signal conditioner, dc-dc converter, and axillary and sternal electrodes.

Electrocardiogram Signal Conditioner - The EKG signal conditioner has a signal wave ranging between 0 and 5 volts peak-to-peak which is representative of inflight heart activity.

Impedance Pneumograph Signal Conditioner - The ZPN signal conditioner and associated electrodes provides flight measurement of transthoracic impedance change. A pair of electrodes are used to measure respiration rate over a wide dynamic range of activity. This conditioner is not used during EVA.

The dc-dc Power Converter - The dc-dc power converter delivers a + 10 and - 10 volt power to each signal conditioner. It converts the single ended 16.8 volt power to the + 10 and - 10 volt power required by the bioinstrumentation systems.

Electrodes - The electrodes are attached directly to the skin with an adhesive disk filled with conductive paste. The EKG sternal electrodes are attached to the EKG signal conditioner and EKG axillary electrodes are attached to the ZPN signal conditioner.

4.5 PLSS Performance Data

A PLSS system flow chart is presented in Figure 4.5-0.1. More detailed performance data of the individual subsystems is presented in the following paragraphs.

4.5.1 Extravehicular Communication System (EVCS)

4.5.1.1 Modes

The EVCS operational modes are defined in Figure 4.5-1. These modes are manually selected by the EVA crewman. The principal operating mode is for both crewmen to be in the dual (AR) mode. This is the only mode in which both crewmen can be received simultaneously. Crewmen should never simultaneously be in either the primary (A) mode or the secondary (B) mode.

4.5.1.2 Voice Communications

The EVCS provides for duplex voice communications between earth and at least one crewman. It also provides for uninterrupted voice communications between both crewmen. The performance requirements of the primary and secondary transceivers are summarized in Table 4.5-1A. FM transmitter and receiver performance requirements are summarized in Table 4.5-1B.

4.5.1.3 Telemetry

The telemetry parameters are identified in Table 4.5-2. In addition, the normal operating ranges of each parameter are listed for pre-egress checkout and for extravehicular activity. The calibration curves for the individual sensors are presented in Figures 4.5-2 through 4.5-8. Telemetry inaccuracies attributed to the sensors and the EVCS are presented in Table 4.5-3.

Table 4.5-3.1 presents the overall accuracy of the EMU biomedical and suit data from the lunar surface to the Mission Control Center. The table is a summary of the estimated errors contributed by each section of the telemetry link for the PLSS and EKG. The last column of the table shows the three sigma accuracy estimate ($3\ e_T$) for each parameter. This accuracy is expressed as a percent of full scale.

All telemetry data from each crewman is commutated on a single subcarrier except EKG data. Each crewman's EKG information in continuously sampled on its own subcarrier. The telemetry channel assignments are given in Table 4.5-4.

Telemetry data is not transmitted when the mode selected is the secondary or "B" mode.

4.5.1.4 Antenna

All EMU communications are transmitted and received via the EMU antenna. The antenna is mounted on the OPS. When mounted with coaxial cable and input connector, it has a VSWR of 2.0:1 or less. The antenna is vertically polarized. A description of the antenna coverage factor is presented in Table 4.5-5.

If the EVC is operated with the EMU antenna stowed, the range from the LM is limited to $\frac{1}{4}$ mile with the possibility of extreme transmitter distortion.

If the EVA antenna on the LM fails during lunar operations, the EV crewmen can maintain communications with MSFN at an estimated maximum range of $\frac{1}{2}$ mile in-line with either the front or aft VHF inflight antenna.

4.5.1.5 EMI Suppression

All lines in and out of each EVC is filtered for EMI suppression, except the left and right microphone wires and the biomedical primary power wire. These three wires just loop through each EVC.

Each communicator is spec'd and tested to accept on the battery supply line a 1.1 volt peak-to-peak noise signal between the frequencies of 250 Hz and 15 KHz, and a 0.55 peak-to-peak noise signal between 30 Hz and 250 Hz.

4.5.1.6 Temporary Out-of-Spec Temperature Indications

When the water diverter valve is first turned to maximum cooling, the LCG differential temperature transducer produces a signal as much as 200% of nominal maximum. This relatively high voltage is fed through to the other temperature transducers driving them out of range. This is only a temporary out-of-spec occurrence, and causes no equipment failure. The condition exists on the PLSS O_2 and LCG inlet H_2O temperature readings for 8 to 10 seconds. The condition exists on the LCG differential temperature readout for 15 to 20 seconds.

Design average heat loads		
Description	Units	Value
abolic heat rate	BTU/hr	1200
gen consumption	lb/hr	0.195
2 production	lb/hr	0.235
ystem heat load	BTU/hr	1179.2
otal system (design point) load	BTU	7116.8
al water storage	lb	6.62
imum water separated	lb	0.35
imum water separated	lb	2.03
al power required	watts	52.16
sion electrical energy	watt-hr	208.64
sion electrical heat load	BTU/hr	200.97

*The system is designed for no prespiration. However the O_2 sublimator must be capable of handling 100 cc/hr of perspiration

General design data		
Description	Units	Value
ign point mission time	hrs	4.0
imum mission time	hrs	4.0
bined fan/motor efficiency		14
p efficiency		11
ery efficiency		0.88
pressure ratio		1.051
/motor power	watts	30.0
p power	watts	10.0
S and electrical components	watts	12.56
gen flex hose I.D.	in.	0.750
gen hardline O.D.	in.	0.750
id flex hose I.D.	in.	0.305

Design point pressure loss	
Oxygen loop (at 6.0 CFM)	In. H_2O
Pressure garment assembly (spec)	1.65
Gas connectors (suit and PLSS)	1.10
LiOH canisters	1.10
Sublimator	1.21
Vent flow sensor	0.20
Water separator	0.32
Ducting	0.32
Backflow check valve	0.25
Pressure rise across fan	5.25
Liquid loop (at 4 lb/min)	psi
Liquid cooling garment	1.780
Connectors	0.800
Diverter valve	0.360
Sublimator	0.795
Fan motor cooling jacket	0.054
Ducting	0.893
Pressure rise across pump	4.682

Figure 4.5-0.1 Apollo EMU Program - PLSS System Flow Chart

EVC UNIT	EVCS FUNCTIONS	MODE	FUNCTION	MODE SELECTOR SWITCH POSITION	NOTES
EVC-1	EKG 5.4, PLSS Data 10.5 KHz; Voice + TM Transmitter 259.7, Voice + TM Receiver 279.0, Voice Receiver 296.8 MHz	Primary transceiver, FM receiver, and telemetry ON	Voice and telemetry to LM for transmission to MSFN; voice to EVC-2 Voice from LM or EVC-2	AR (Dual Mode)	Transmitter continually operative (not activated by voice operated switch)
EVC-2	EKG 3.9, PLSS Data 7.35 KHz; Voice Receiver 259.7, Voice + TM Transmitter 279.0, Voice Receiver 296.8 MHz	FM transmitter, Primary & Secondary Receivers, and telemetry ON	Voice and telemetry to EVC-1 for transmission to LM Voice from LM and EVC-1	AR (Dual Mode)	Transmitter continually operative (not activated by voice operated switch)
EVC-1 or EVC-2	EKG EVC-2 3.9, EKG EVC-1 5.4, PLSS Data EVC-2 9.35, PLSS Data EVC-1 10.5 KHz; Voice + TM Transmitter 259.7, Voice Receiver 296.8 MHz	Primary transceiver and telemetry ON	Voice and telemetry to LM for transmission to MSFN Voice from other EVC and LM	A (Primary Mode)	Transmitter continually operative (not activated by voice operated switch)
EVC-1 or EVC-2	Voice Receiver 259.7, Voice Transmitter 296.8 MHz	Secondary transceiver ON	Voice to LM for transmission to MSFN Voice from LM (Backs up primary transceiver for emergency voice communication)	B (Secondary Mode)	No telemetry capability Transmitter inoperative unless activated by voice operated switch or manual switch

Figure 4.5-1 Extravehicular Communications System Operational Modes

Table 4.5-1A Voice Communications - Amplitude Modulated

RECEIVER	PRIMARY	SECONDARY
Frequency	296.8 MHz ± 9 KHz	259.7 MHz ± 7.8 KHz
Bandwidth	Superheterodyne 70 KHz IF at 6 db min	Superheterodyne 70 KHz IF at 6 db min
Output	12.6 mw min to helmet isolation network	12.6 mw min to helmet isolation network

TRANSMITTER		
Frequency	259.7 MHz ± 7.8 KHz	296.8 MHz ± 9 KHz
Bandwidth	Compatible with data being transmitted	Down 2 db maximum at 300 Hz and 2.3 KHz
Power Output	250 mw min unmodulated at antenna terminal	250 mw min unmodulated at antenna terminal

Table 4.5-1B Voice Communications - Frequency Modulated

RECEIVER (EVC-1)	
Frequency	279.0 MHz ± 8.4 KHz
Bandwidth	125 KHz IF at 3 db min
Power Output	12.6 mw min to helmet isolation network

TRANSMITTER (EVC-2)	
Frequency	279.0 MHz ± 8.4 KHz
Bandwidth	Compatible with data being transmitted
Power Output	316 mw min unmodulated at antenna terminal

Table 4.5-2 Telemetry

TELEMETRY IDENTIFICATION	PARAMETER	PRE-EGRESS CHECKOUT	EXTRAVEHICULAR ACTIVITY
GT 8110P/8210P	Feedwater Pressure	1.6 to 3.5 psia	1.6 - 3.5 psia
GT 8124J/8224J	Electrocardiogram		
GT 8140C/8240C	PLSS Battery Current	EVC only - 0.6 amps EVC and fan - 1.9 amps EVC fan & pump - 2.4 amps	2.0 - 3.0 amperes
GT 8141V/8241V	PLSS Battery Voltage	16.0 - 20.5	16.0 - 20.5
GT 8154T/8254T	LCG Inlet Water Temp-erature	40° - 90°F	40° - 90°F
GT 8168P/8268P	PGA Pressure	3.75 to 5.0 psia	3.75 to 4.0 psia
GT 8182P/8282P	PLSS O_2 Pressure	850 to 950 psia	350 to 950 psia
GT 8196T/8296T	LCG H_2O ΔT	0° - 15°F	0° - 15°F
GT 8170T/8270T	PLSS O_2 Temperature	38 - 52°F	38 - 52°F
GT 8100X/8200X	EVC Sync	N/A	N/A
GT8101V/8201V	Zero Calibration	N/A	N/A
GT8102V/8202V	Full Scale Calibration	N/A	N/A

Table 4.5-2 Telemetry

TELEMETRY IDENTIFICATION	PARAMETER	PRE-EGRESS CHECKOUT	EXTRAVEHICULAR ACTIVITY
GT 8110P/8210P	Feedwater Pressure	1.6 to 3.5 psia	1.6 - 3.5 psia
GT 8124J/8224J	Electrocardiogram		
GT 8140C/8240C	PLSS Battery Current	EVC only - 0.6 amps EVC and fan - 1.9 amps EVC fan & pump - 2.4 amps	2.0 - 3.0 amperes
GT 8141V/8241V	PLSS Battery Voltage	16.0 - 20.5	16.0 - 20.5
GT 8154T/8254T	LCG Inlet Water Temperature	40° - 90°F	40° - 90°F
GT 8168P/8268P	PGA Pressure	3.75 to 5.0 psia	3.75 to 4.0 psia
GT 8182P/8282P	PLSS O_2 Pressure	850 to 950 psia	350 to 950 psia
GT 8196T/8296T	LCG H_2O Δ T	0° - 15°F	0° - 15°F
GT 8170T/8270T	PLSS O_2 Temperature	38 - 52°F	38 - 52°F
GT 8100X/8200X	EVC Sync	N/A	N/A
GT8101V/8201V	Zero Calibration	N/A	N/A
GT8102V/8202V	Full Scale Calibration	N/A	N/A

Table 4.5-3 PLSS-SV706100-6 EVCS/Sensor Instrumentation Inaccuracies

PARAMETER	TM CODE NUMBER	ALLOWABLE INACCURACIES	
		ENGINEERING UNITS	% OF FULL SCALE
PGA Pressure	GT8168P/GT8268P	$\pm$ .1 psi	$\pm$ 4%
Feedwater Pressure	GT8110P/GT8210P	$\pm$ .15 psi	$\pm$ 3%
Battery Current	GT8140C/GT8240C	$\pm$ .15 A	$\pm$ 1.5%
Battery Voltage	GT8141V/GT8241V	$\pm$ .277 V	$\pm$ 3.18%
PLSS O_2 Pressure	GT8182P/GT8282P	$\pm$ 27.5 psi	$\pm$ 2.5%
LCG ΔT	GT8196T/GT8296T	$\pm$ 0.5°F	$\pm$ 3.3 %
LCG Inlet Temp.	GT8154T/GT8254T	$\pm$ 3.96°F	$\pm$ 4.4%
PLSS O_2 Temp.	GT8170T/GT8270T	$\pm$ 3.96°F	$\pm$ 4.4%

Table 4.5-3.1 Overall Accuracy of EMU Telemetry Data (Est.)

PARAMETER	EMU				R.F. Links		MSFN Low Pass Filter		PAM/PCM Converter		MSFN SCO		MCC Dis-criminator		MCC Low Pass Filter		Σe^2	e_T	$3e_T$
	Full Scale	Accuracy Limits	e (%)	$e^2 \times 10^4$	e (%)	$e^2 \times 10^4$	e (%)	$e^2 \times 10^4$	e (%)	$e^2 \times 10^4$	e (%)	$e^2 \times 10^4$	e (%)	$e^2 \times 10^4$	e (%)	$e^2 \times 10^4$	$\times 10^4$	%	%
Primary Oxygen Pressure	0-1110 psia	±2.5 %	0.83	0.694	0.50	0.250	0	0	0.40	0.160	--	--	--	--	--	--	1.104	1.05	3.15
Sublimator Feedwater Pressure	0-5 psia	±3.0 %	1.00	1.000	0.50	0.250	0	0	0.40	0.160	--	--	--	--	--	--	1.410	1.19	3.57
LCG Inlet Temperature	40-90°F	±4.4 %	1.47	2.151	0.50	0.250	0	0	0.40	0.160	--	--	--	--	--	--	2.561	1.60	4.80
LCG Differential Temperature	0-15° F	±3.3 %	1.10	1.210	0.50	0.250	0	0	0.40	0.160	--	--	--	--	--	--	1.620	1.27	3.81
PGA Pressure	2.5-5.0 psia	±4.0 %	1.33	1.778	0.50	0.250	0	0	0.40	0.160	--	--	--	--	--	--	2.188	1.48	4.44
PLSS Oxygen Temperature	40-90°F	±4.4 %	1.47	2.151	0.50	0.250	0	0	0.40	0.160	--	--	--	--	--	--	2.561	1.60	4.80
Battery Current	0-10 amps	±1.5 %	0.50	0.250	0.50	0.250	0	0	0.40	0.160	--	--	--	--	--	--	0.660	0.81	2.43
Battery Voltage	12.0-20.5 VDC	±3.18 %	1.06	1.124	0.50	0.250	0	0	0.40	0.160	--	--	--	--	--	--	1.534	1.24	3.72
EKG (Commander)	---	---	1.00	1.000	0.68	0.455	0.38	0.144	---	---	1.0	1.000	0.18	0.032	2.00	4.000	6.631	2.57	7.71
EKG (LM Pilot)	---	---	1.00	1.000	0.68	0.455	0.38	0.144	---	---	1.0	1.000	0.18	0.032	1.10	1.210	3.841	1.96	5.88

NOTE: This table is based upon information and procedures outlined in TRW Report, "Overall Accuracy of EMU Biomedical Suit Data," TRW No. 11176-H241-R0-00, dated June 2, 1969

TABLE 4.5-4 - PLSS/EVCS COMMUNICATIONS TELEMETRY CHARACTERISTICS

Measurement title	Instrumentation range	Discriminator output voltage range (DC)	Commutator channels
Zero calibration	0 VDC	0	1
Full scale calib	5 VDC	5	2
PGA pressure	2.5 to 5.0 psid	0-5	3,14,21,24,27
Feed water press.	0 to 5.0 psia	0-5	4,15,22,25,26
Battery current	0 to 10 amps	0-5	5,11
Battery voltage	15.5 to 20.5 volts DC	0-5	6,20
Water diff. temp	0 to 15 F. deg.	0-5	8,19
LCG inlet temp.	40° to 90° F	3.13 to 1.86	9,17
Sublimator gas outlet temp.	40° to 90° F	3.13 to 1.86	10,16
Primary O_2 press.	0 - 1110 psia	0-5	7,12, 13, 18,23,28
Syncronization	———	Double width pulse	29,30

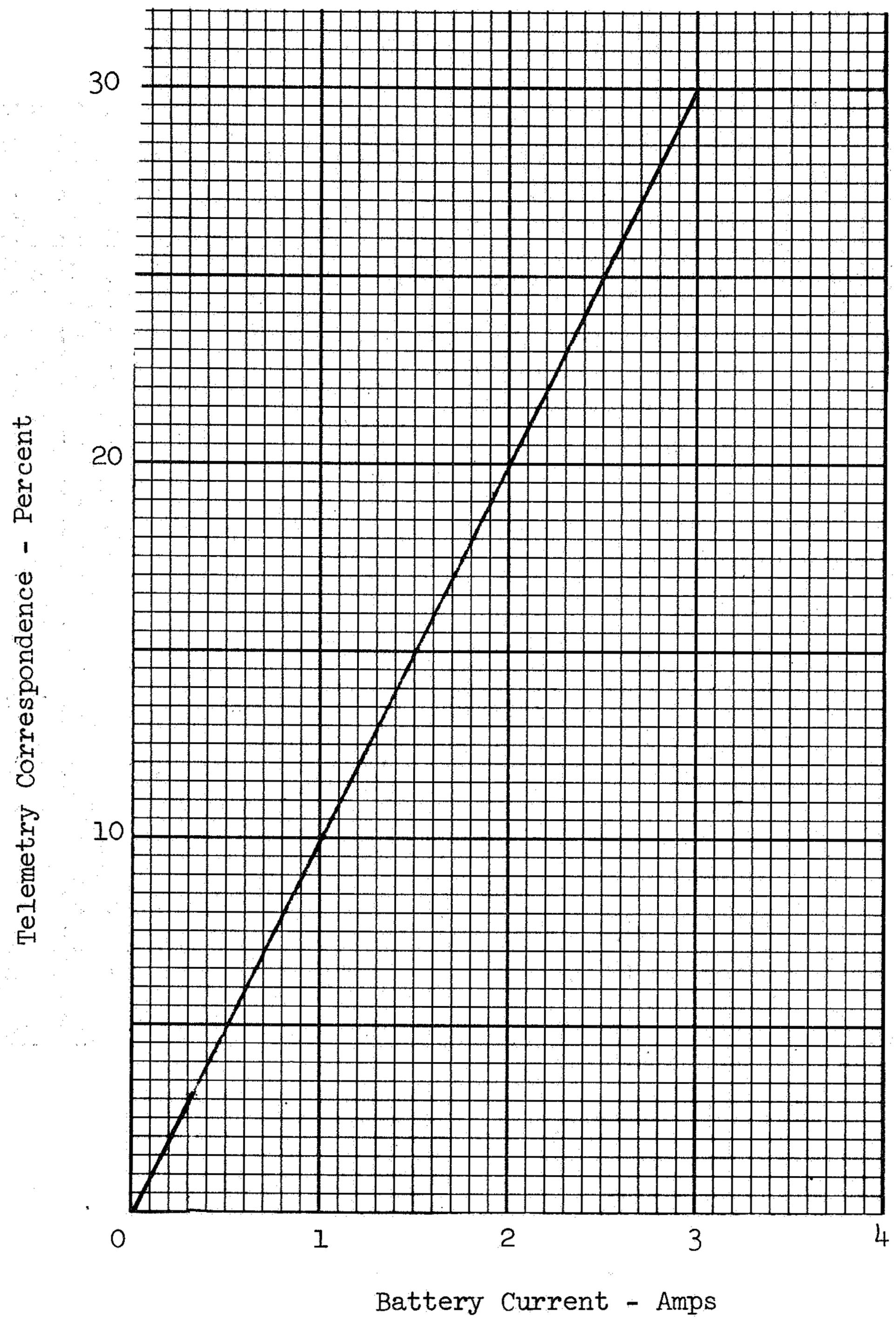


Figure 4.5-4 Battery Current Calibration Curve

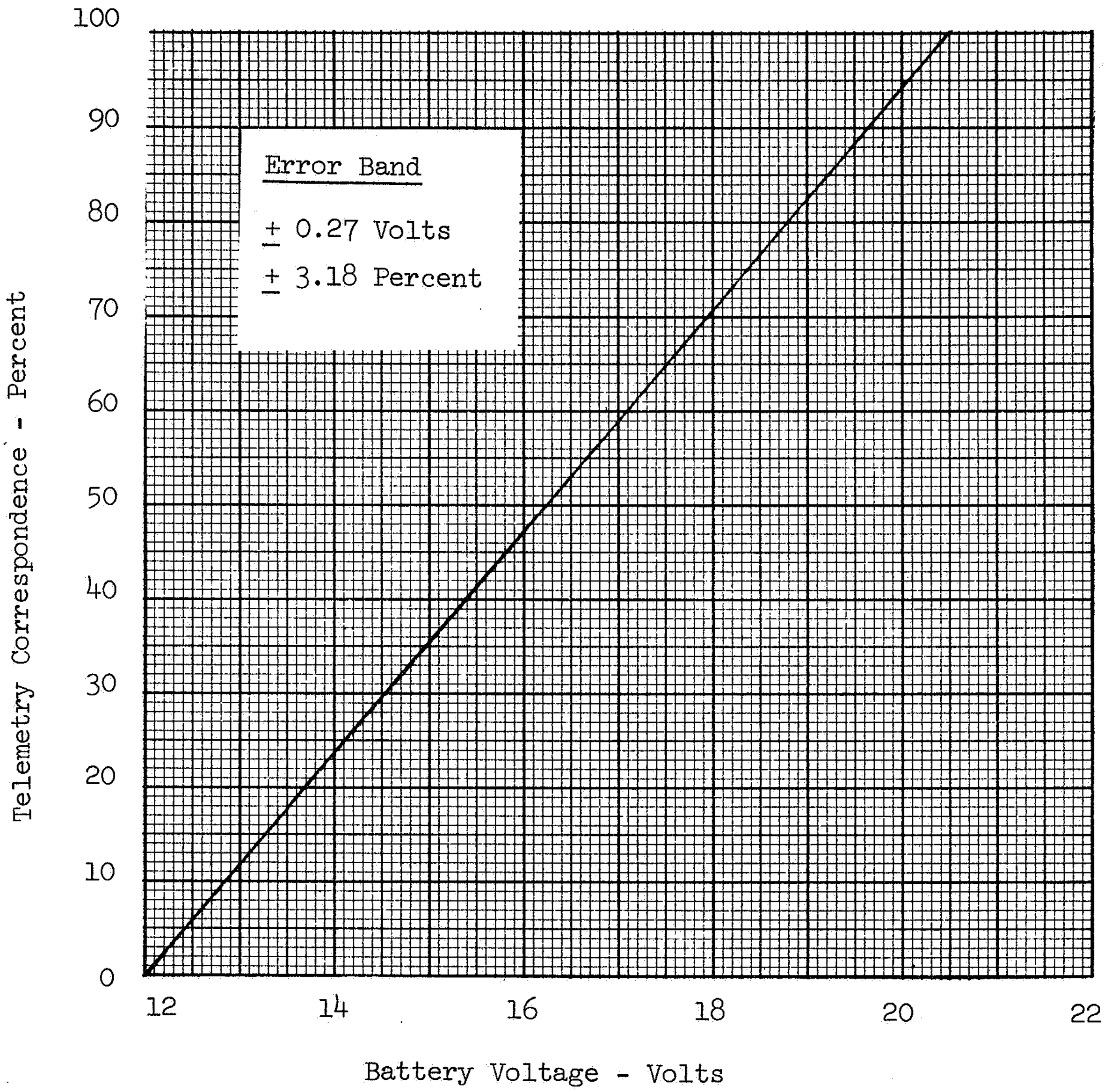


Figure 4.5-5 Battery Voltage Calibration Curve

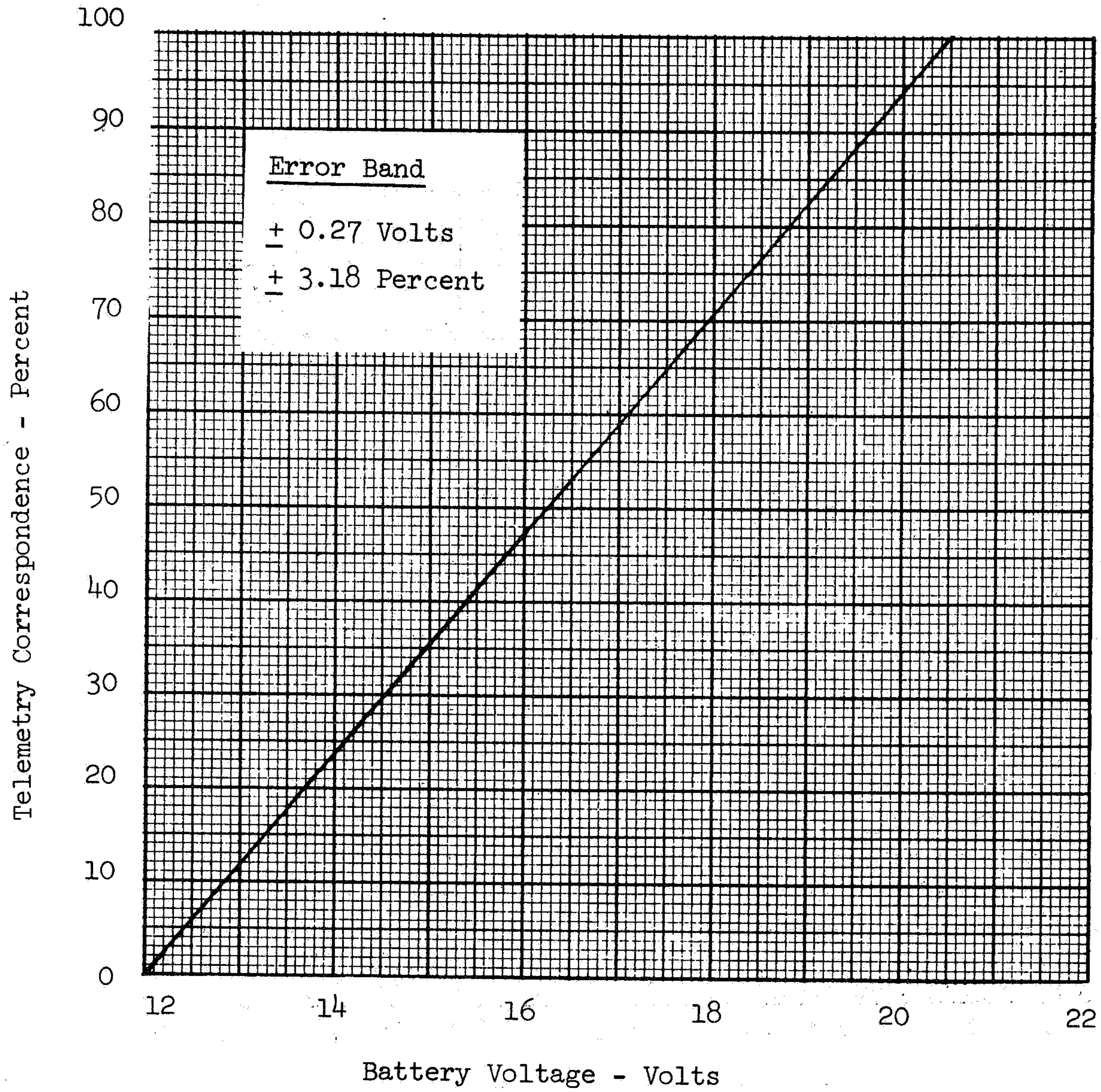


Figure 4.5-3 Battery Voltage Calibration Curve

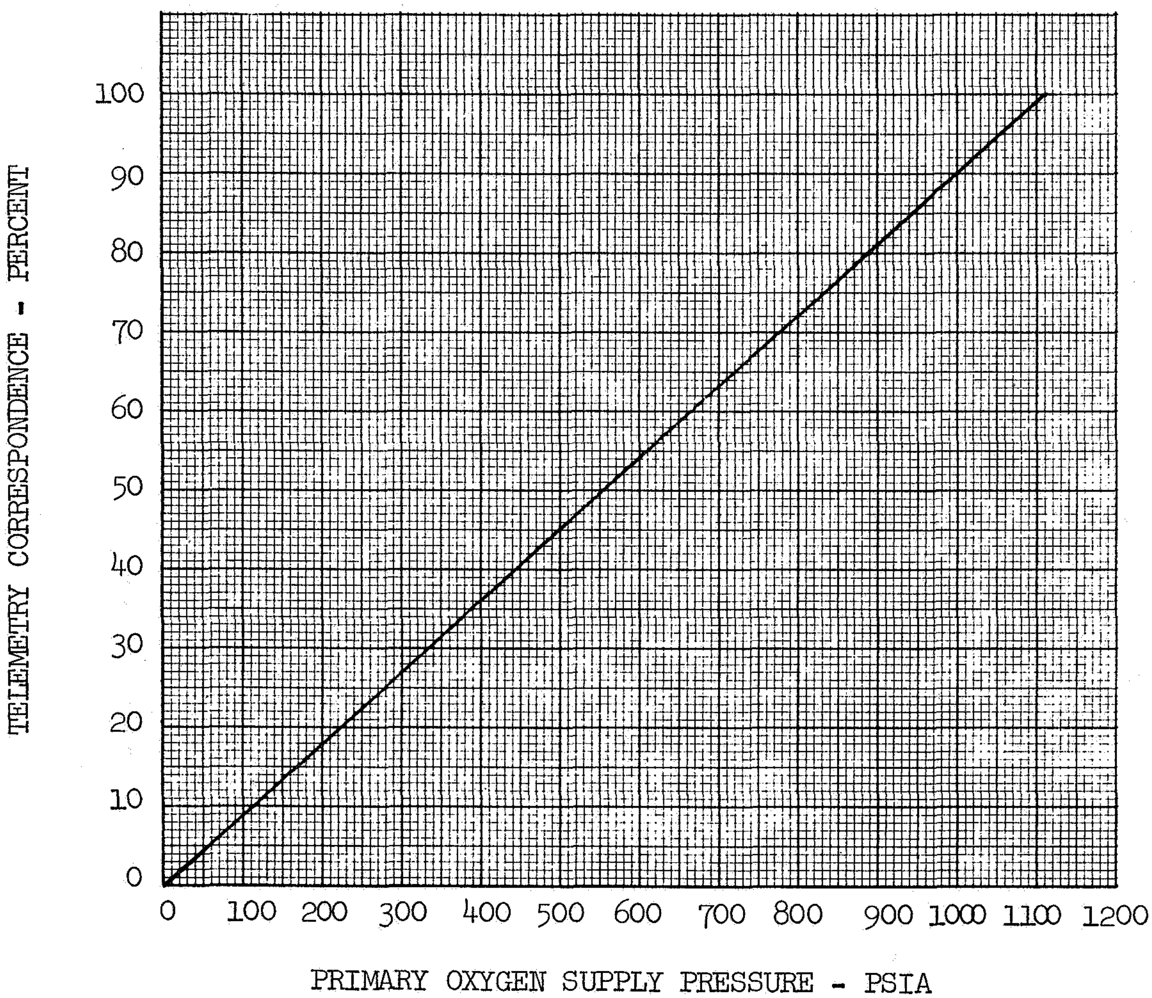


Figure 4.5-4 POS Pressure Calibration Curve

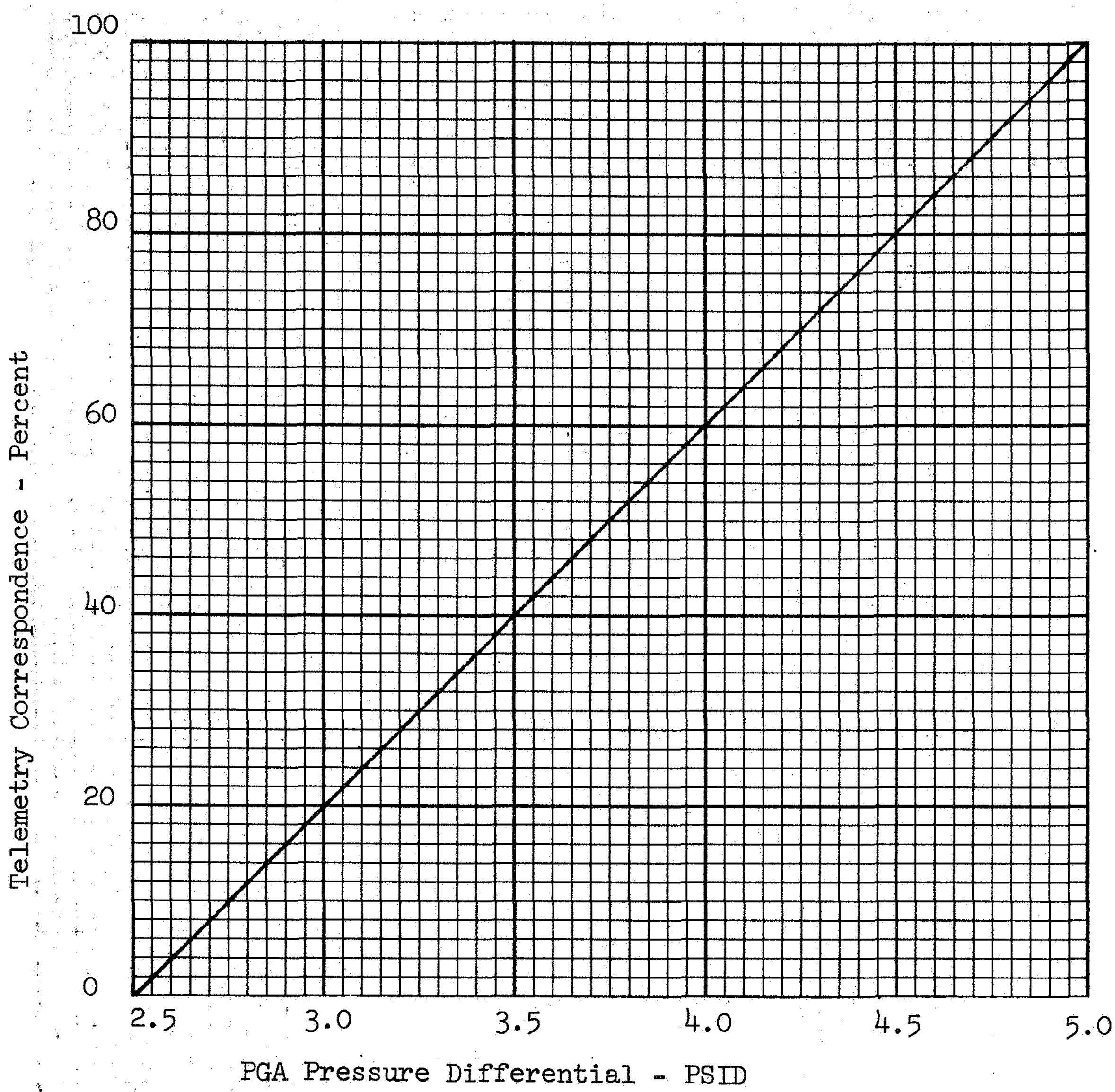


Figure 4.5-8 PGA Pressure Differential Pressure Calibration Curve

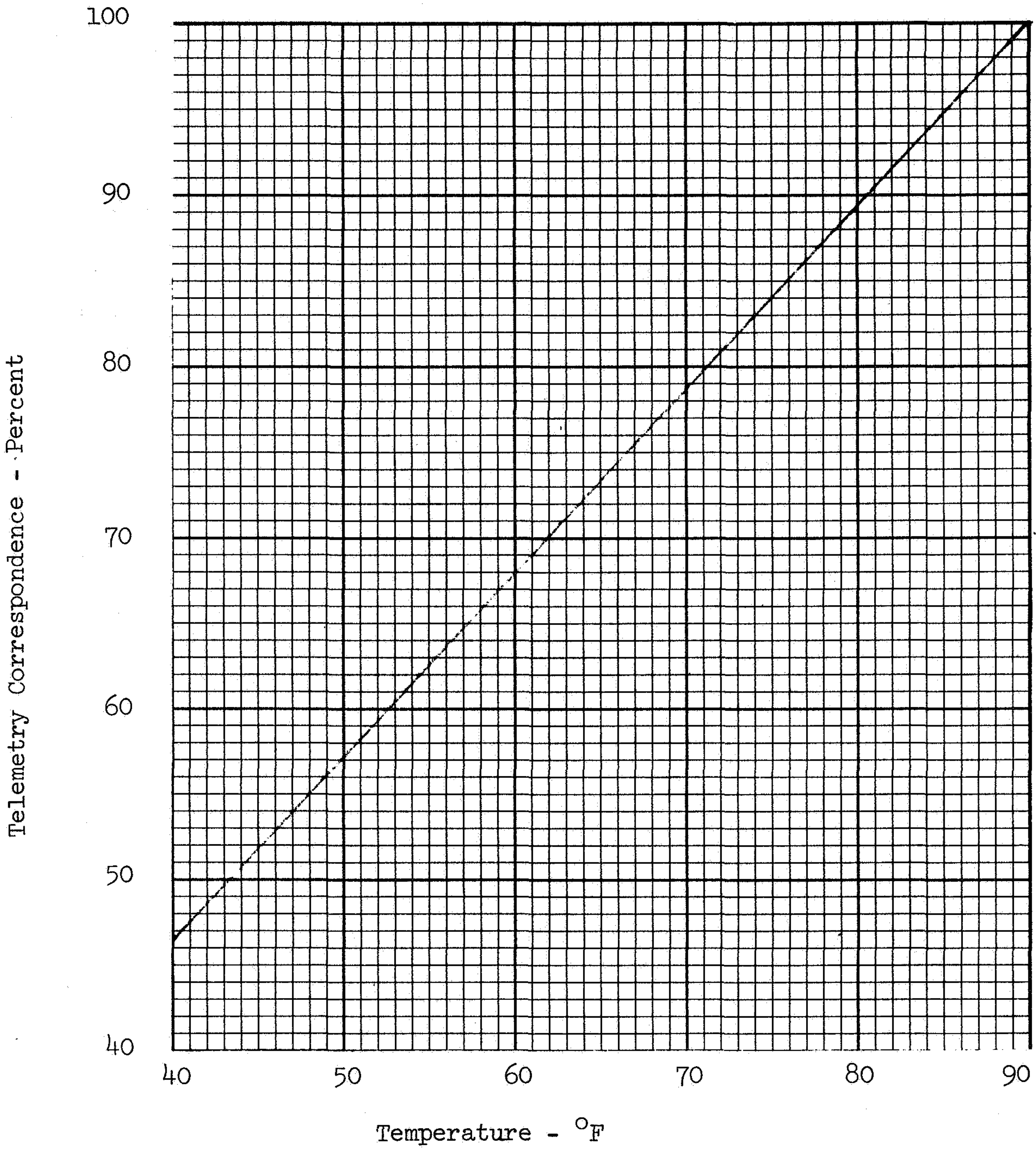


Figure 4.5-9 LCG Inlet H_2O Temperature Calibration Curve

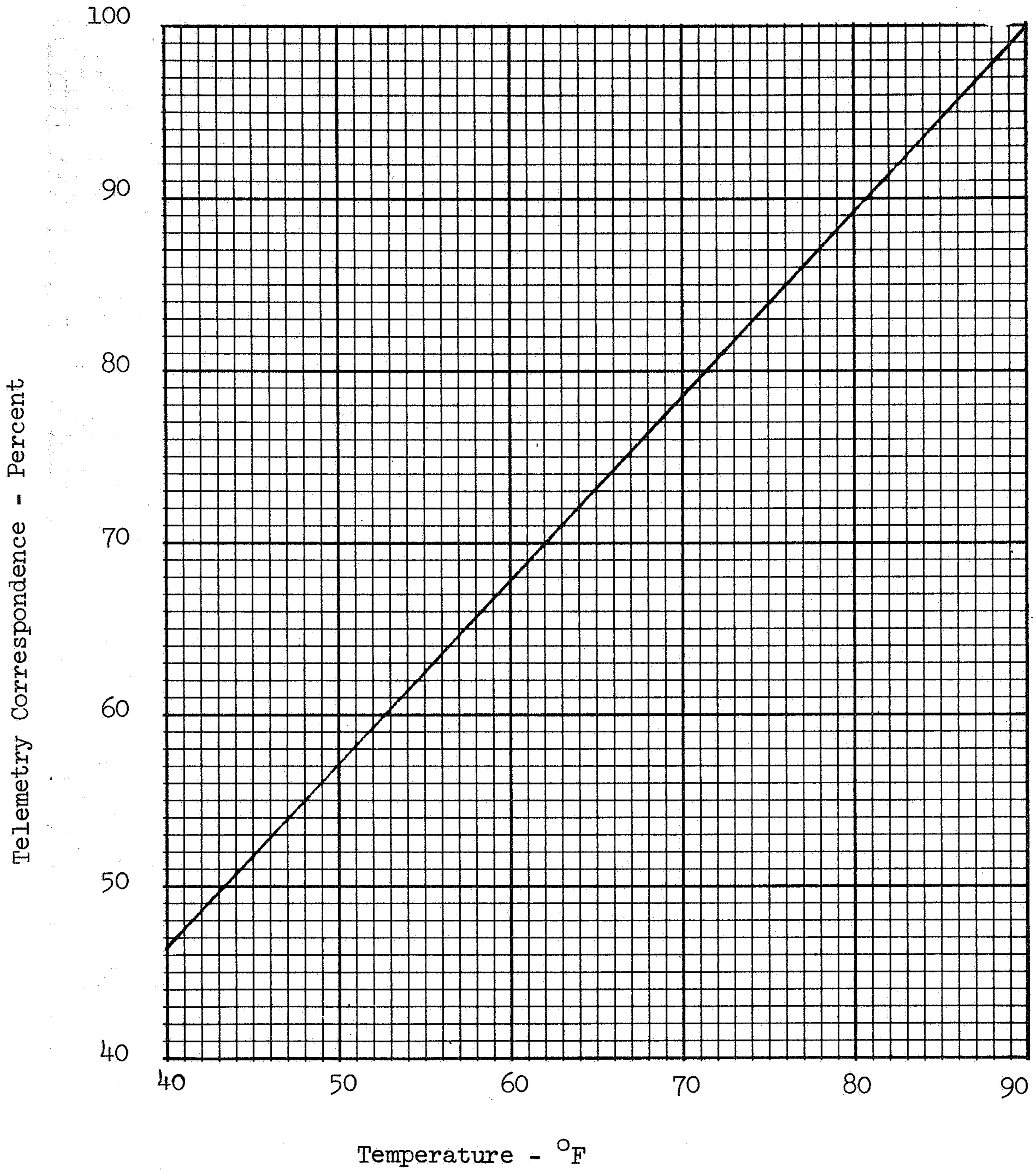


Figure 4.5-10 PLSS O_2 Temperature Calibration Curve

Figures 4.5-11 through 4.5-18

Pages 4.5-16 through 4.5-24

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4.5.1.5 EMU Warning System

The EMU Warning System characteristics are summarized in Table 4.5-6 on page 4.5-19.

General Description

Four sensors are situated at various points in the PLSS to give warning of potentially dangerous conditions. If one of these transducers senses a dangerously low pressure or a high or low flow rate, it signals the PLSS Alarm Control Module. The Alarm Control Module generates a warble warning tone through the Extra-vehicular Communications System to the Astronaut's earphones. It also activates one of five visual warning indicators which are located on the Remote Control Unit at the front of the space suit.

The "High Primary Oxygen Flow" Warning

One of the four sensors is located just downstream of the Primary Oxygen Pressure Regulator. If the regulator passes a flow which exceeds 0.50 to 0.65 lbs/hour for a period of time greater than five seconds, the warning tone will sound in the crewman's earphones, and the visual warning flag labeled "O_2" will pop up on the RCU. This warning flag will reveal a lighted symbol "O," which indicates "OPS" actuation needed. After 10 $\pm$ 2 seconds, the tone will stop sounding, but the flag will remain raised until the flow is less than 0.50 to 0.65 lbs/hour. Then, the flag will drop automatically.

The "Low PGA Pressure" Warning

To give warning of low suit pressure, a low pressure switch is located in the primary oxygen make-up flow line of the PLSS. This transducer is just downstream of the High Primary Oxygen Flow Sensor discussed above. Upon sensing a pressure lower than 3.10 to 3.40 psid, the switch actuates the warning tone, and the warning flag labeled "Press." on the RCU in the manner described above. This warning flag will reveal a lighted symbol "O" meaning "Actuate OPS." As in all the warning tone soundings, the tone will last 10 $\pm$ 2 seconds, regardless of when the PGA pressure goes back to above 3.10 to 3.40 psid, but as with all the warning flags, this flag will remain raised until the PGA pressure returns to 3.10 to 3.40 psid or higher at which time it will drop automatically.

The "Low Vent Flow" Warning

A transducer is located just downstream of the Fan in the PLSS vent loop. If this transducer senses a flow rate lower than 4.0 to 5.3

acfm for a period of time greater than five seconds, the warning tone will sound for 10 ± 2 seconds. The warning flag labeled "Vent" on the RCU will pop up and reveal a lighed symbol "P" meaning "Purge." The flag will remain raised until the fan flow returns to 4.0 to 5.3 or higher, at which time it will drop to the closed position.

Prior to flight, the sensor activation and deactivation points are required to be between 4.7 and 5.0 acfm; however, for the second EVA, these points nominally experience a 0.1-0.2 cfm downward shift depending upon the amount of water condensed in the electronic element.

The "Low Feedwater Pressure" Warning

The fourth transducer is located in the feedwater line just upstream of the sublimator. If the feedwater pressure drops below 1.30 to 1.60 psia, the warning tone will sound for 10 ± 2 seconds and an RCU flag will pop up to reveal a lighted "A" symbol indicating "Abort." The flag will remain raised until the feedwater pressure is again higher than 1.30 to 1.60 psia. This same transducer is used to telemeter the feedwater pressure reading to ground control.

Additional Warning System Characteristics

Although there are five warning flags on the RCU, only the four described above are operational. The fifth flag, labeled "CO_2," is intended for use on later models of the EMU. Each warning flag is lighted by a Beta light source capsule which requires no electric power.

If the EVCS mode selector switch position is changed, the warning tone will again come on for 10 ± 2 seconds, provided one of the four transducers is still signaling for a warning tone.

The warning tone is a 1.5 KHz frequency tone which is interrupted fifteen times per second to give a warbling sound. The tone is clearly audible above the transceiver output in transmitting, receiving, or standby operations.

Table 4.5-6 Warning System

PARAMETER	ACTUATION AND DEACTUATION BAND	WARNING TONE		WARNING FLAG			REMARKS
		FREQUENCY	DURATION	OUTER LABEL	INNER SYMBOL	DURATION	
High Oxygen Flow	> 0.50 - 0.65 lbs/hour	1.5 KHz	10±2 sec.	O_2	O	Until flow < 0.50-0.65 lbs/hr.	5 second time delay
Low PGA Pressure	< 3.10-3.40 psid	1.5 KHz	10±2 sec.	Pres.	O	Until pressure > 3.10-3.40 psid	
Low Vent Flow	< 4.0-5.3 acfm	1.5 KHz	10±2 sec.	Vent	P	Until flow > 4.0-5.3 acfm	5 second time delay
Low Feedwater Pressure	< 1.30 - 1.60 psid	1.5 KHz	10±2 sec.	H_2O	A	Until pressure > 1.30-1.60 psid	

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4.5.2 PLSS Electrical Subsystem

4.5.2.1 Battery

The PLSS power supply is a replaceable silver zinc battery with a two sigma capacity of 279 watt-hours (16.5 amp-hours) and an operational output voltage of 16.0 to 20.5 volts. The battery is composed of eleven cells, each cell having a pressure differential of 8.0 ± .3 psid. This relief capability is provided by an unsophisticated valve verified only at the time of delivery by the battery supplier. The total battery is contained in a sealed case that incorporates a pressure relief valve which maintains the pressure differential between 4.9 and 8.0 psid.

The output voltage and capacity vary with temperature as shown in Figure 4.5-17. This figure was determined for a 60 watt load which represents the load for which the battery was designed. Figure 4.5-18 shows the discharge curve for the battery with a 40 watt load discharged under ambient conditions. The 40 watt load is representative of the nominal load imposed by the PLSS and EV communicator (reference Table 4.5-8).

To prevent battery degradation due to time-temperature limitation, the battery should be stored and used in accordance with Table 4.5-7.

Figures 4.5-17 and 4.5-18 show that the battery voltage begins to fall sharply approximately thirty minutes before exhaustion of the power supply (16.0 vdc).

4.5.2.2 Current Limiters

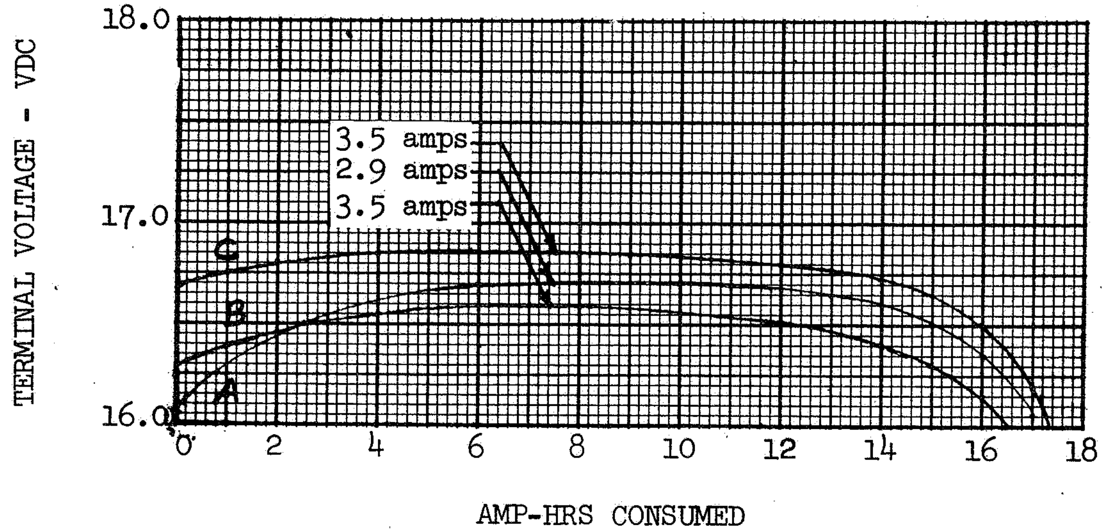
Current limiters are used in the PLSS to protect the circuits shown in Table 4.5-9. These current limiters can withstand current loadings in excess of their rating for short time periods as shown in Figure 4.5-20.

4.5.2.3 Voltage Degradation Effects

A test was performed at NASA/CSD to determine the effect of degrading voltage upon the EMU subsystems performance. The test started with a voltage of 17.1 volts which was decreased at 0.1 volt increments. The low vent flow flag and warning tone actuated at 14.2 volts. This was attributed to degraded fan performance and the actuation was normal when flow was reduced. No tests were conducted below 14.2 volts to check the warning tone or flag actuations; however, all flags remained in the cleared position throughout the test. No significant degradation of communication or telemetry was evident until the supply voltage was reduced to 13.6 vdc. At this point, the signal from the PLSS/EVCS had degraded to the extent that the RF ground station could not translate the telemetered data. At 12.5 vdc, the voice comm transmitted by the PLSS/EVCS was unintelligible. The EKG and all transmitting power was lost at 12.0 vdc. The voice comm received by the PLSS/EVCS was understandable until the voltage reached 9.5 vdc.

Throughout the test, fan and pump degradation was evident by progressively lower flow rates and Delta P's in the gas and transport loops.

At the conclusion of the test, the voltage was returned to 17.0 volts and normal operation was obtained.



CURVE A

BATTERY AGE 3 YEARS
HOT TEMPERATURE SOAK

TEMP	TIME
90°F	168 Hrs
100	72
120	48
50	8

50° AT START OF DISCHARGE SVHSER 5529

CURVE B

BATTERY AGE 1 YR. MAX.
COLD TEMPERATURE SOAK

TEMP	TIME
100°F	100 Hrs
35	30
50	1

50° AT START OF DISCHARGE SVHSER 5177

CURVE C

BATTERY AGE 1 YR. MAX.
HOT TEMPERATURE SOAK

TEMP	TIME
90°F	50 Hrs
100	50
130	30

105° AT START OF DISCHARGE SVHSER 5177

Figure 4.5-17 Voltage Discharge Profile

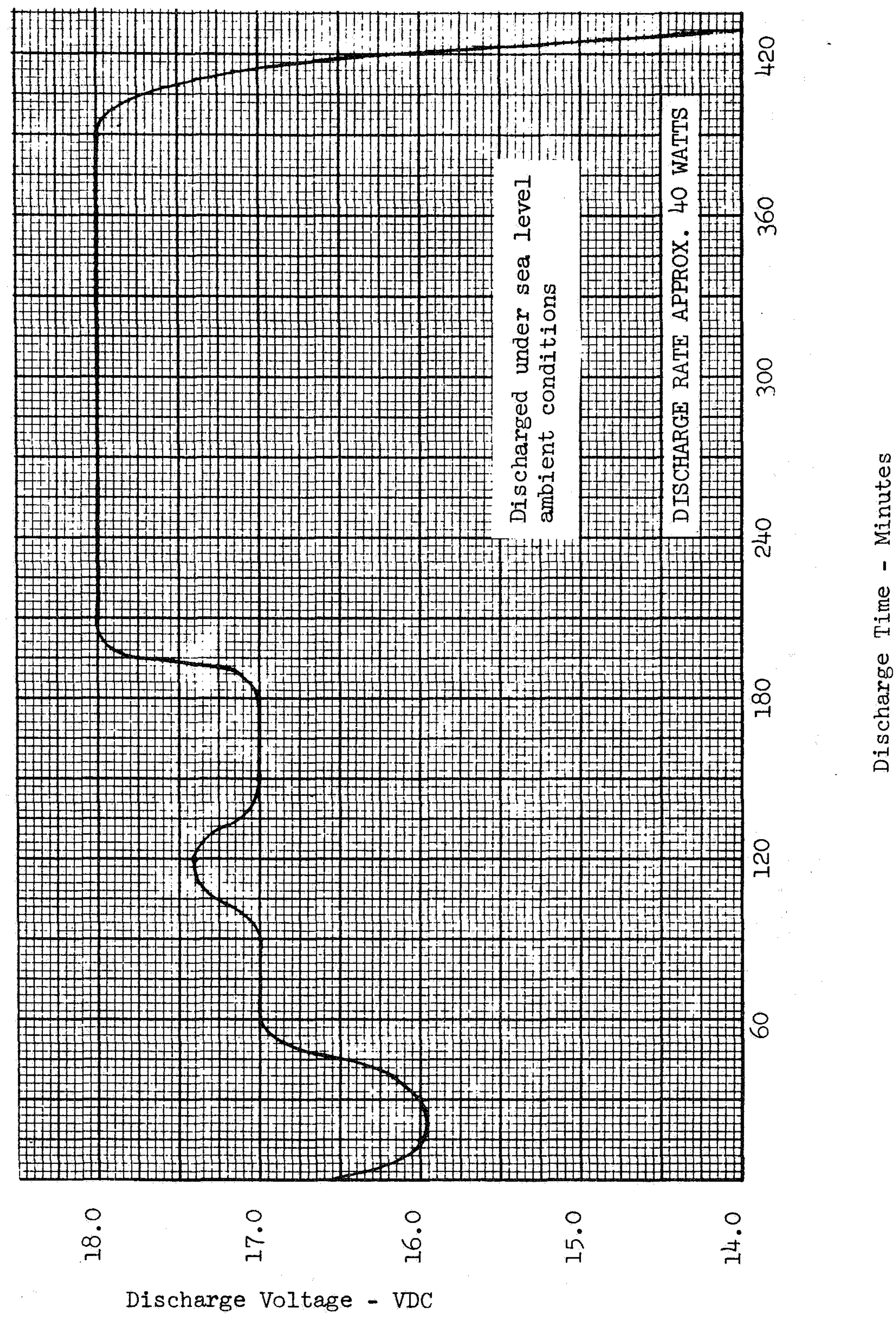


Figure 4.5-18 PLSS Battery Voltage Versus Discharge Time

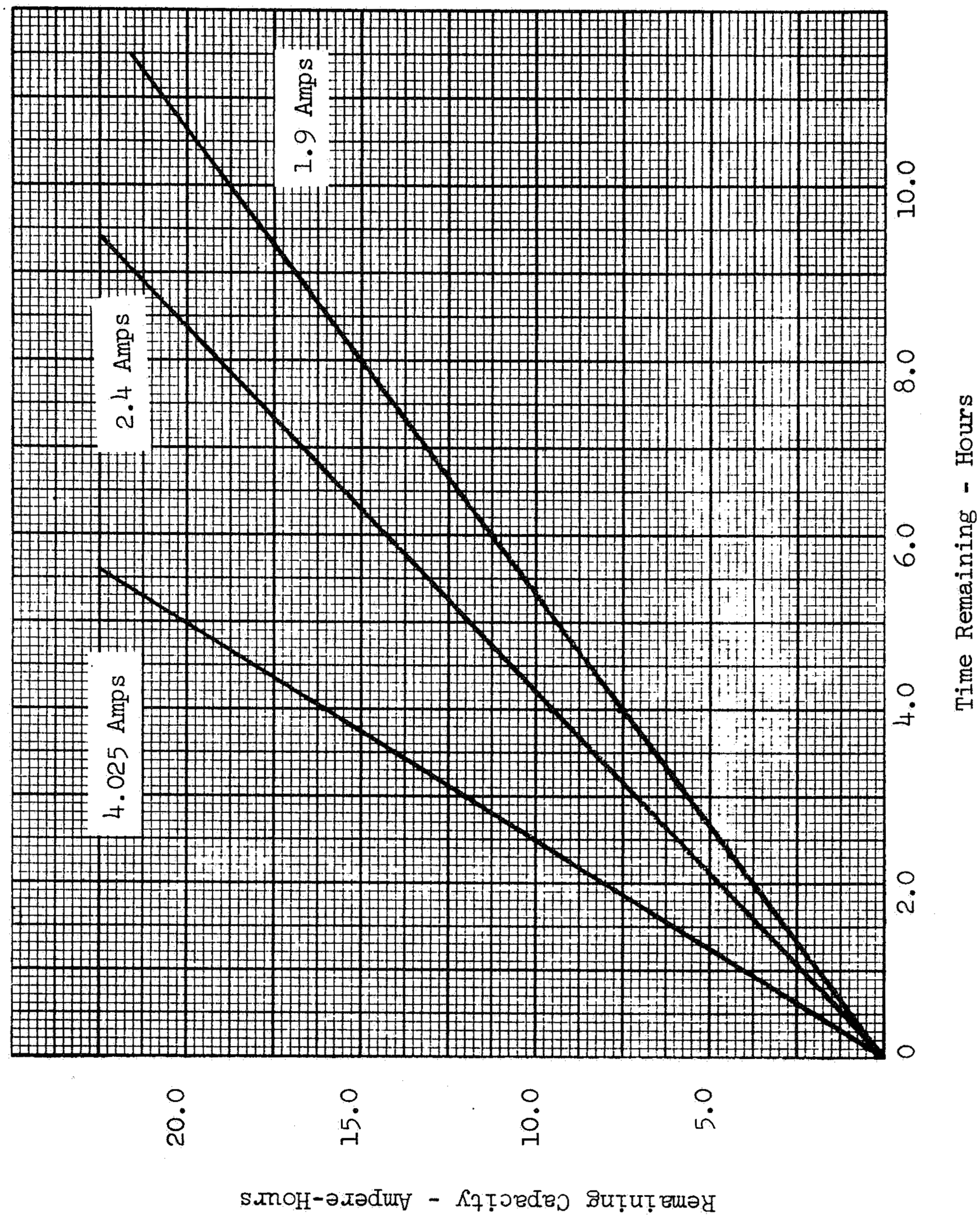


Figure 4.5-19 PLSS Battery Ampere-Hours Remaining Vs. Time Remaining

Table 4.5-7 PLSS Power Supply Storage and Usage Time-Temperature Limitations

CONDITION OF POWER SUPPLY	TEMPERATURE LIMITATION	TIME AT TEMPERATURE LIMIT
Storage, Unactivated	35° to 110°F	1 year maximum
Storage, Activated		12 days total life
(a)	50° to 80°F	12 days maximum
(b)	0° to 50°F 80° to 100°F	5 days maximum
(c)	100° to 130°F	2 days maximum
Operation		
(a)	50° to 90°F	At start
(b)	70° to 160°F	Between 2.0 and 4.0 hours

CAUTION: The battery should not be allowed to exceed 160°F as plate warpage and battery degradation will occur.

Table 4.5-8 PLSS Power Profile

	Nominal Current	Electrical Heat Loading
Fan	1.3 amps	74.5 BTU/Hr
Pump	0.5 amps	28.6 BTU/Hr
EVC		
Dual Mode	0.6 amps	34.4 BTU/Hr
Primary Mode	0.6 amps	34.4 BTU/Hr
Secondary Mode	0.5 amps	28.6 BTU/Hr
TOTAL (EVC in Dual or Primary Mode)	2.4 amps	137.6 BTU/Hr
TOTAL (EVC in Secondary Mode)	2.3 amps	131.9 BTU/Hr

NOTE: For real-time consumables evaluation, the telemetry data should be used.

Table 4.5-5 Current Limiter Usage and Ratings

COMPONENT(S) PROTECTED	RATING
Fan	Current protection not provided* (#22 gage wire)
Pump	Current protection not provided* (#22 gage wire)
Vent Flow Sensor	1/16 amp (62.5 ma)
Time Delay Module (Vent Flow Sensor)	1/16 amp (62.5 ma)
High O_2 Flow Sensor	None externally - has 50 ma limiter built in
Time Delay Module (High O_2 Flow Sensor)	1/16 amp (62.5 ma)
Left Microphone	1/8 amp (125 ma) with series 32.4-39.2 ohm $\frac{1}{2}$ watt resistor
Right Microphone	1/8 amp (125 ma) with series 32.4-39.2 ohm $\frac{1}{2}$ watt resistor
EVC Warning Tone Generator	1/16 amp (62.5 ma)
Alarm Module	$\frac{1}{2}$ amp (500 ma)
EVC Telemetry Voltage Regulator	1 amp
EKG	$\frac{1}{4}$ amp (250 ma) with series 32.4-39.2 ohm $\frac{1}{2}$ watt resistor
Transducer Voltage Regulators	One only current limiter rated at 3/4 amp (750 ma)
EVC Dual-Primary Mode Voltage Regulator	2 amp
EVC Secondary Mode Voltage Regulator	2 amp

*Maximum overload current approximately 40 amps

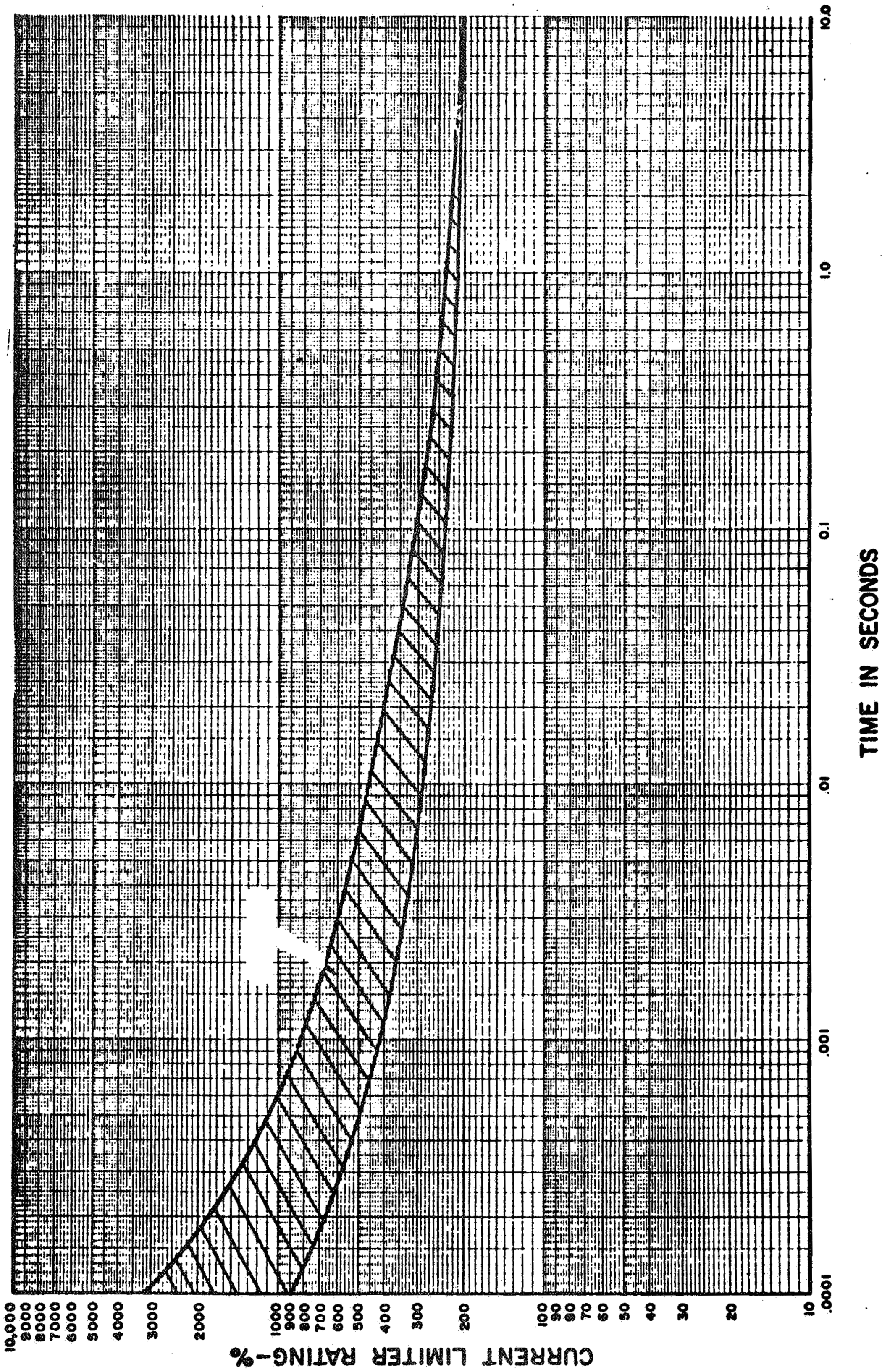


Figure 4.5-20 Current Limiter Rating Versus Time

4.5.3 Ventilation Loop

The pressure rise versus flow characteristics of the PLSS ventilation loop are shown in Figure 4.5-25. Superimposed on this figure is the pressure drop of the PGA.

4.5.3.1 Fan Performance

The PLSS fan circulates PGA life supporting atmosphere gasses through the PLSS ventilation loop for cooling and for carbon dioxide, odor, and moisture removal within the PGA. The fan operates in gasses which are at 3.85 $\pm$ .15 psia pressure, and 38 to 52°F temperature on the inlet side. The gas pressure rise due to the fan is compared to the pressure drop in the PGA for a range of flow rates as shown in Figure 4.5-25. Nominally a minimum flow of 5.5 acfm at 1.5 inches of water pressure rise will be delivered by the fan. CO_2 washout capability as a function of fan flow rate is given in Figure 4.5-25.1. CO_2 buildup as a function of time for the zero ventilation flow condition is shown in Figure 4.5-25.2.

The fan is driven by a dc motor which operates at a nominal 16.8 volts with 1.3 amperes current draw. The relationship between fan current and O_2 vent loop pressure is shown in Figure 4.5-26, while the fan power consumption versus flow rate (at constant voltage) is given in Figure 4.5-27. Figure 4.5-28 relates fan pressure rise to flow rate for three operating voltages.

The fan/motor operates at a speed of 18,600 $\pm$ 600 RPM under normal loads. The relationship between voltage and RPM at several constant torques are given in Figure 4.5-29.

4.5.3.2 LiOH Cartridge

The PLSS LiOH Cartridge performance characteristics are shown in Figure 4.5-30. This figure results from limited test data, and is included to define the operating characteristics rather than predict cartridge operating time remaining. Water production rates and heat production rates versus CO_2 production rates are given in Figures 4.5-31 and 4.5-32, respectively. CO_2 production, as a function of the metabolic rate, is shown in Figure 4.5-33. For discussion of the physiological effects CO_2 refer to NASA SP-3006, "Bioastronautics Data Book", Section I, page 8.

The allowable time/temperature envelope for LiOH storage is given in Figure 4.5-34.

4.5.3.3 Ventilation Loop Sublimator

The ventilation loop portion of the sublimator cools the recirculating oxygen and condenses water vapor. The heat loads on the ventilation

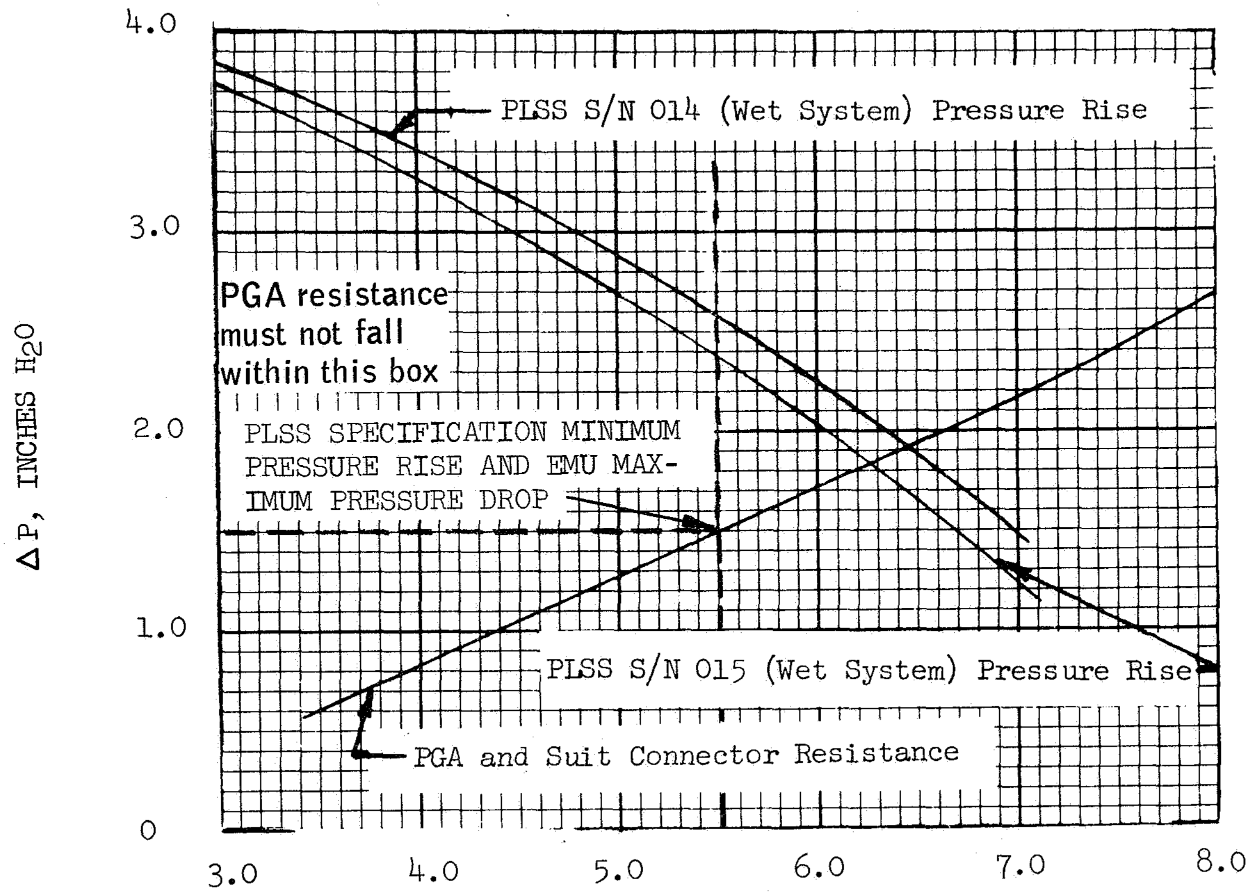
4.5.3.3 Ventilation Loop Sublimator (Cont'd)

loop sublimator, as a function of metabolic rate, are shown in Figure 4.5-35. The figure includes the latent perspiration load which results from a perspiration rate of 100 cc/hour. Although the liquid cooled system is designed to prevent perspiration, the sublimator is designed to handle 100 cc/hour of perspiration.

Ventilation loop sublimator performance data is provided in Figures 4.5-36 through 4.5-38.

4.5.3.4 Ventilation Flow Sensor

The ventilation flow sensor actuates a warning tone at ventilation flow rates of 4.0 to 5.3 acfm for EVA initiated in a LM environment between 60 and 90°F. For EVA initiated in abnormal LM environment, the sensor actuates at flows of 3.5 to 5.4 acfm.



ACFM
PLSS OUTLET PRESSURE:
3.85 ± .15 PSIA

Figure 4.5-25 EMU OXYGEN FLOW PERFORMANCE

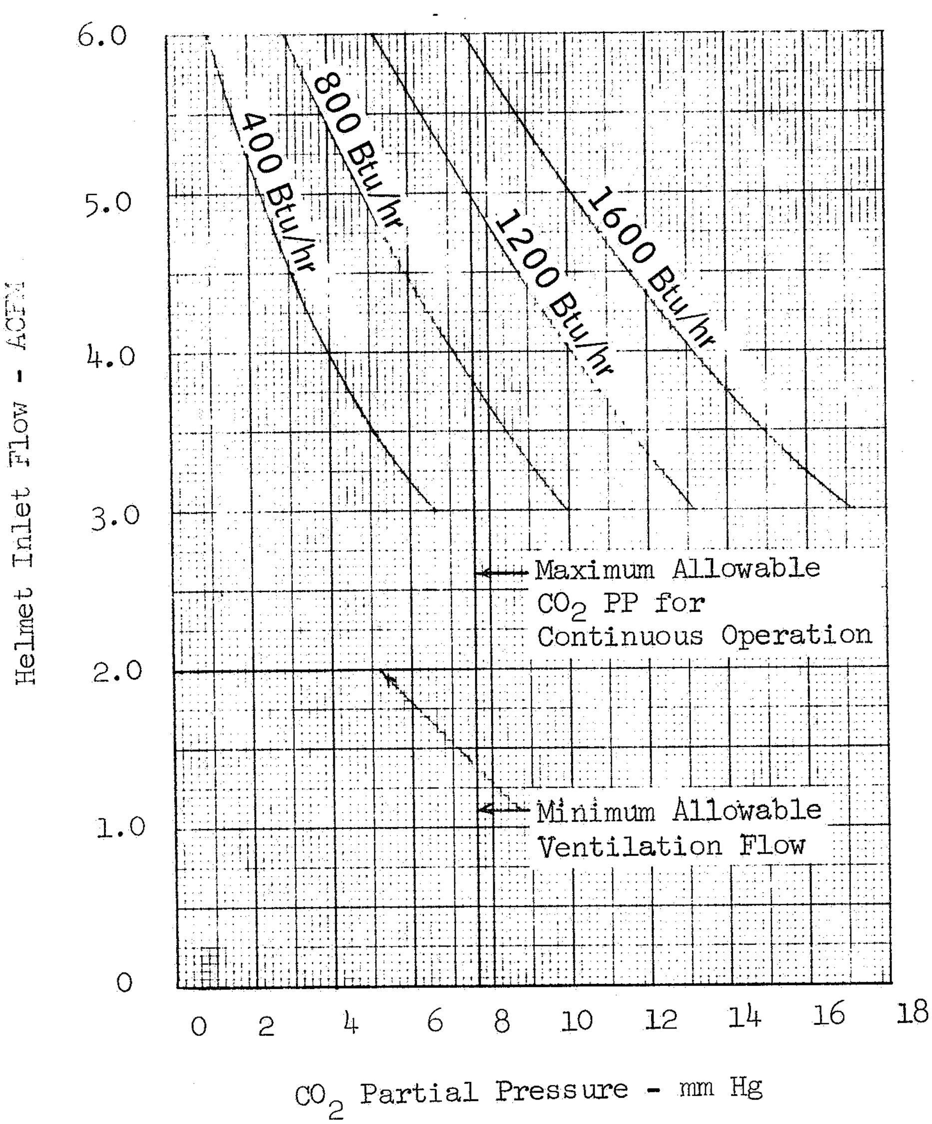


Figure 4.5-25.1 Oral-Nasal CO_2 Levels For Various Metabolic Rates

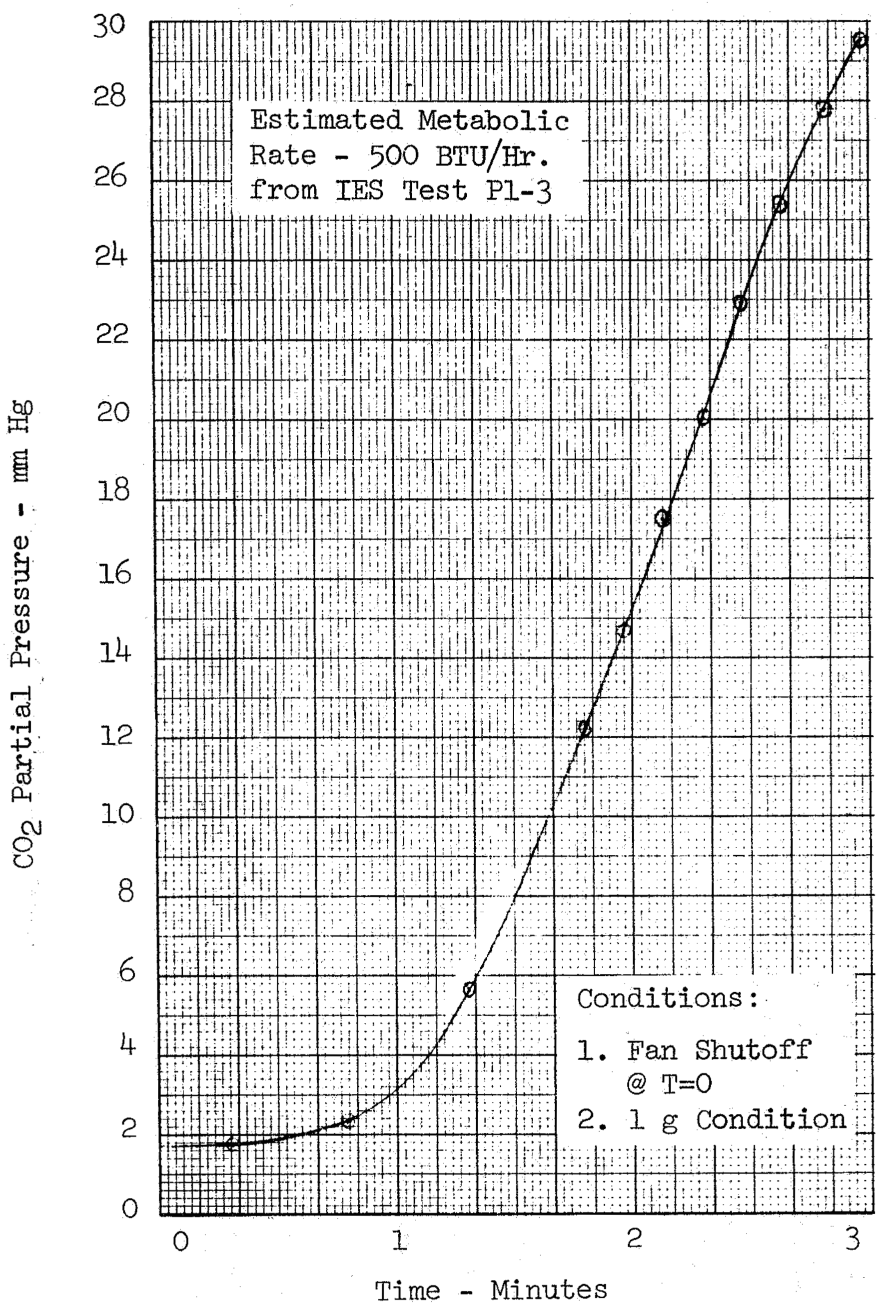


Figure 4.5-25.2 Suit Helmet CO_2 Buildup Without Ventilation Flow

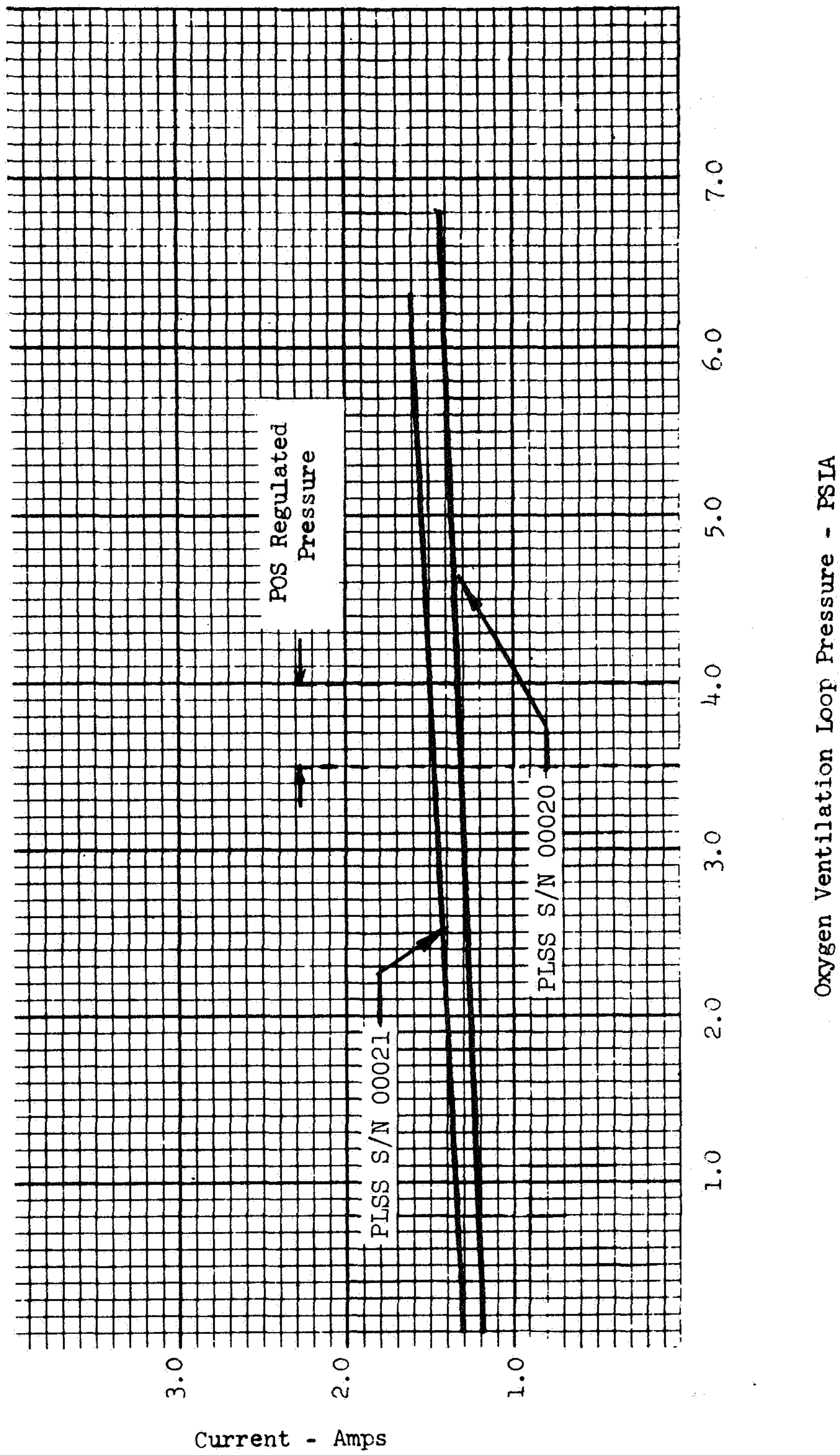


Figure 4.5-26 O_2 Ventilation Loop Pressure Vs. Fan Current Drain

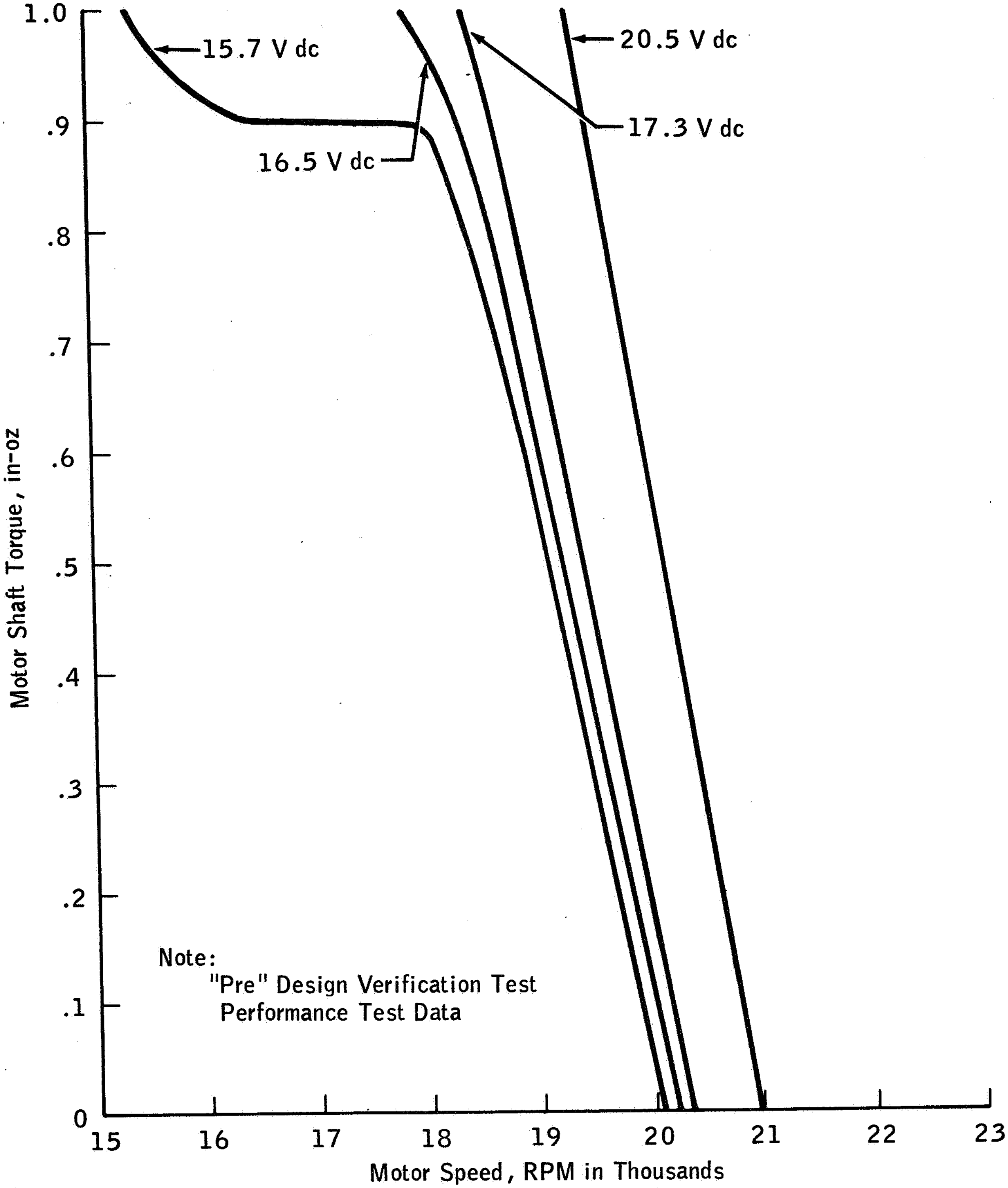


Figure 4.5-28.1 Torque vs Speed for PLSS fan

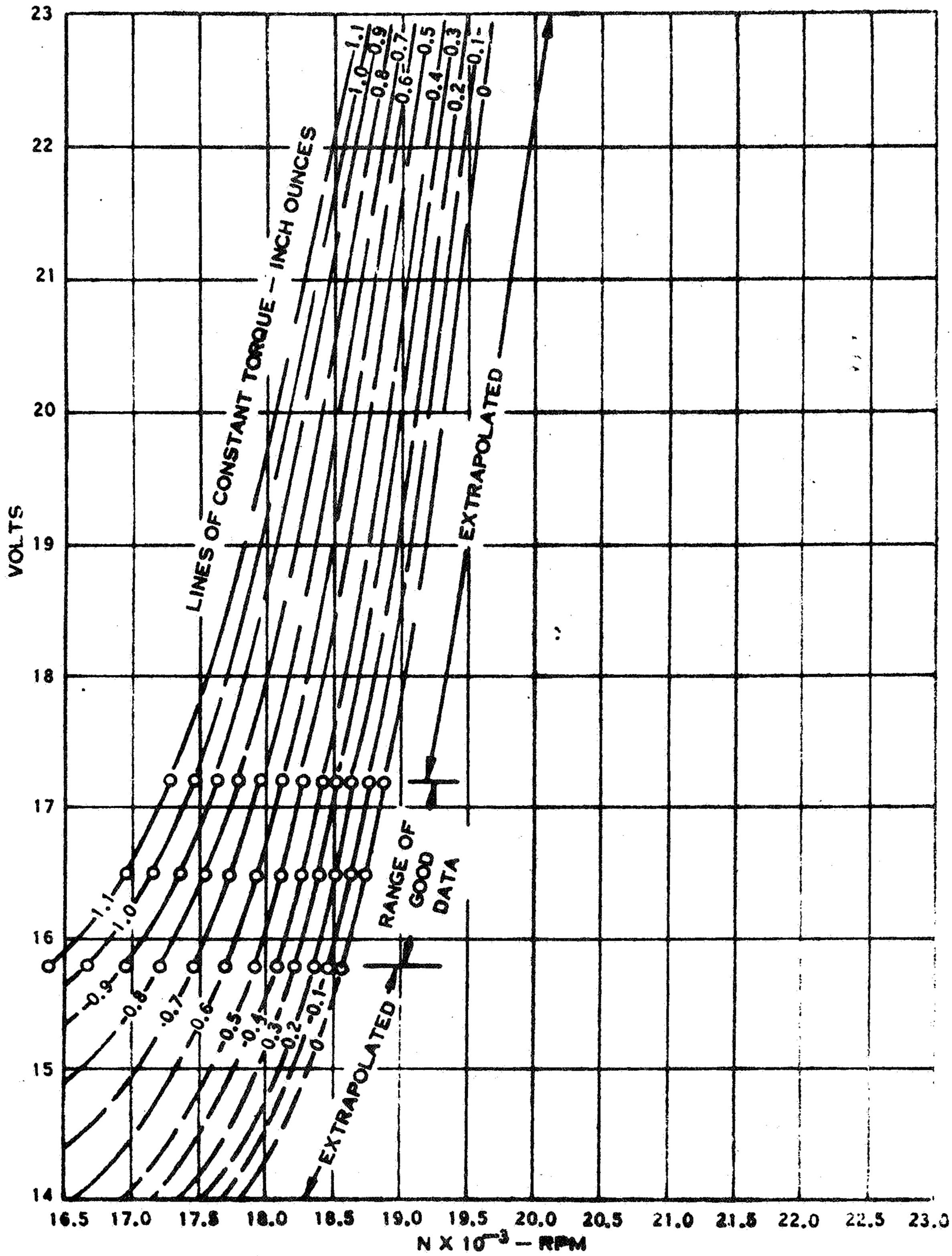


Figure 4.5-29 Fan Motor RPM Vs. Supply Voltage

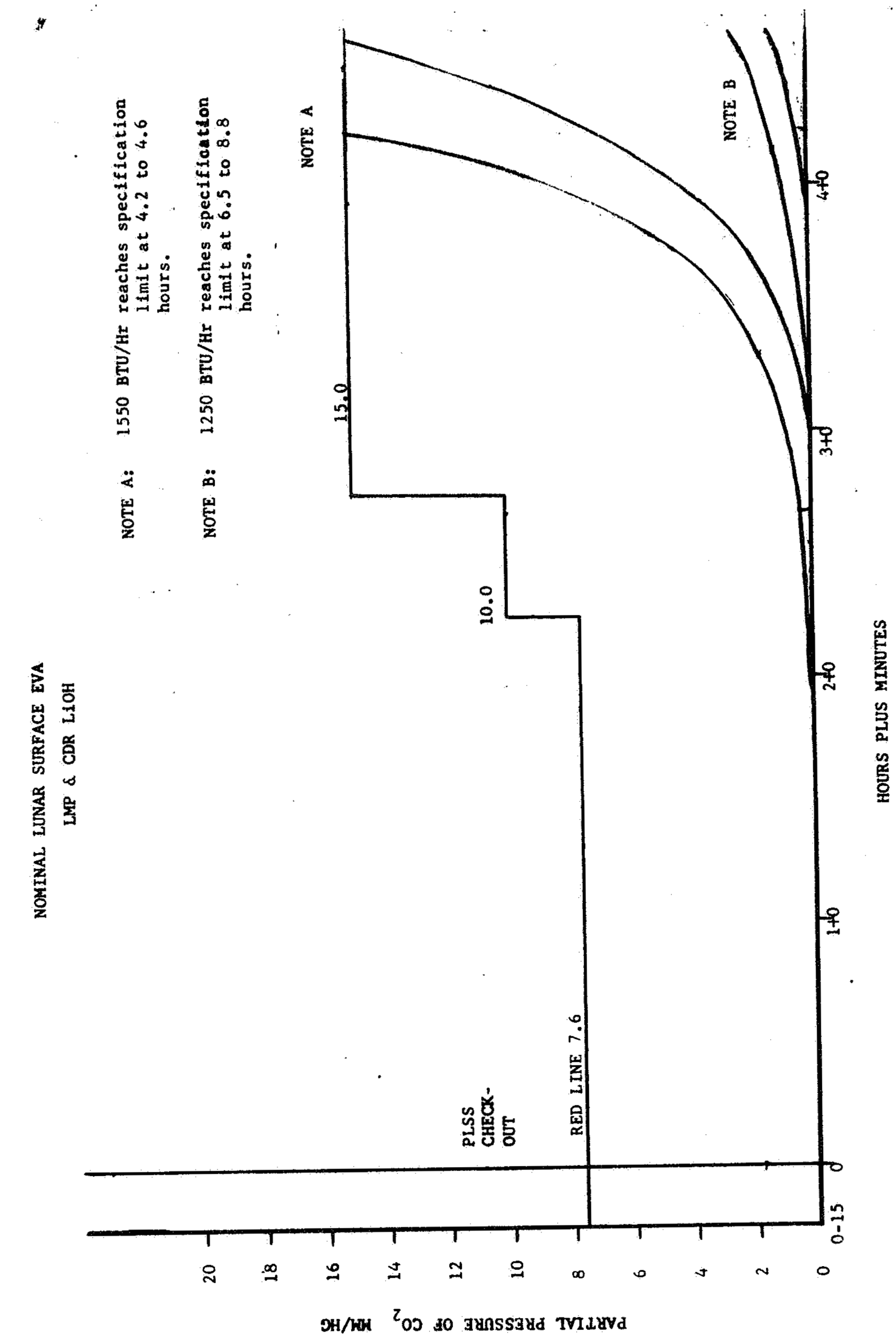


Figure 4.5-30 LMP and CDR CO_2 Buildup (LiOH Depletion)

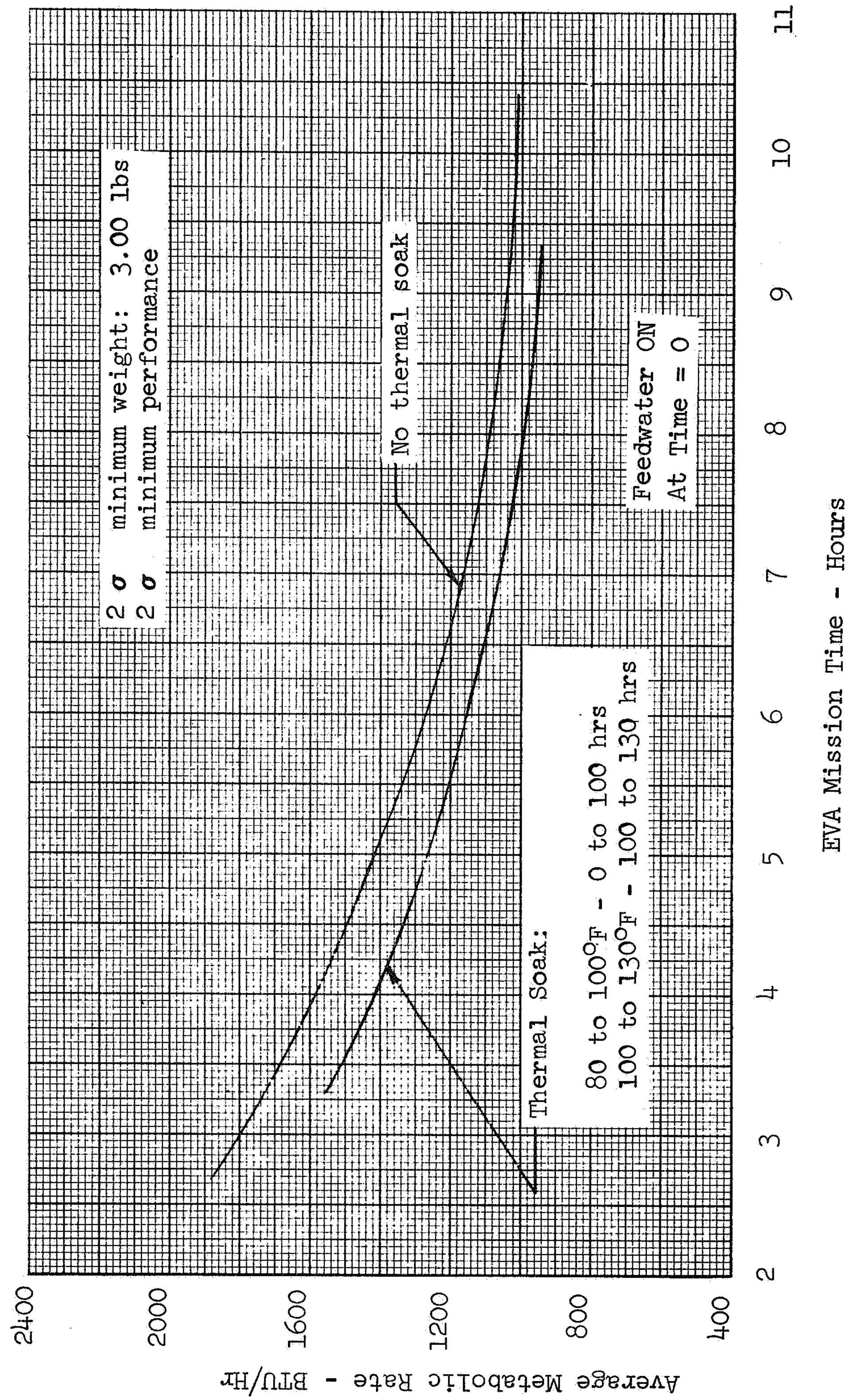


Figure 4.5-30.1 LiOH Cartridge Time Versus Average Metabolic Rate

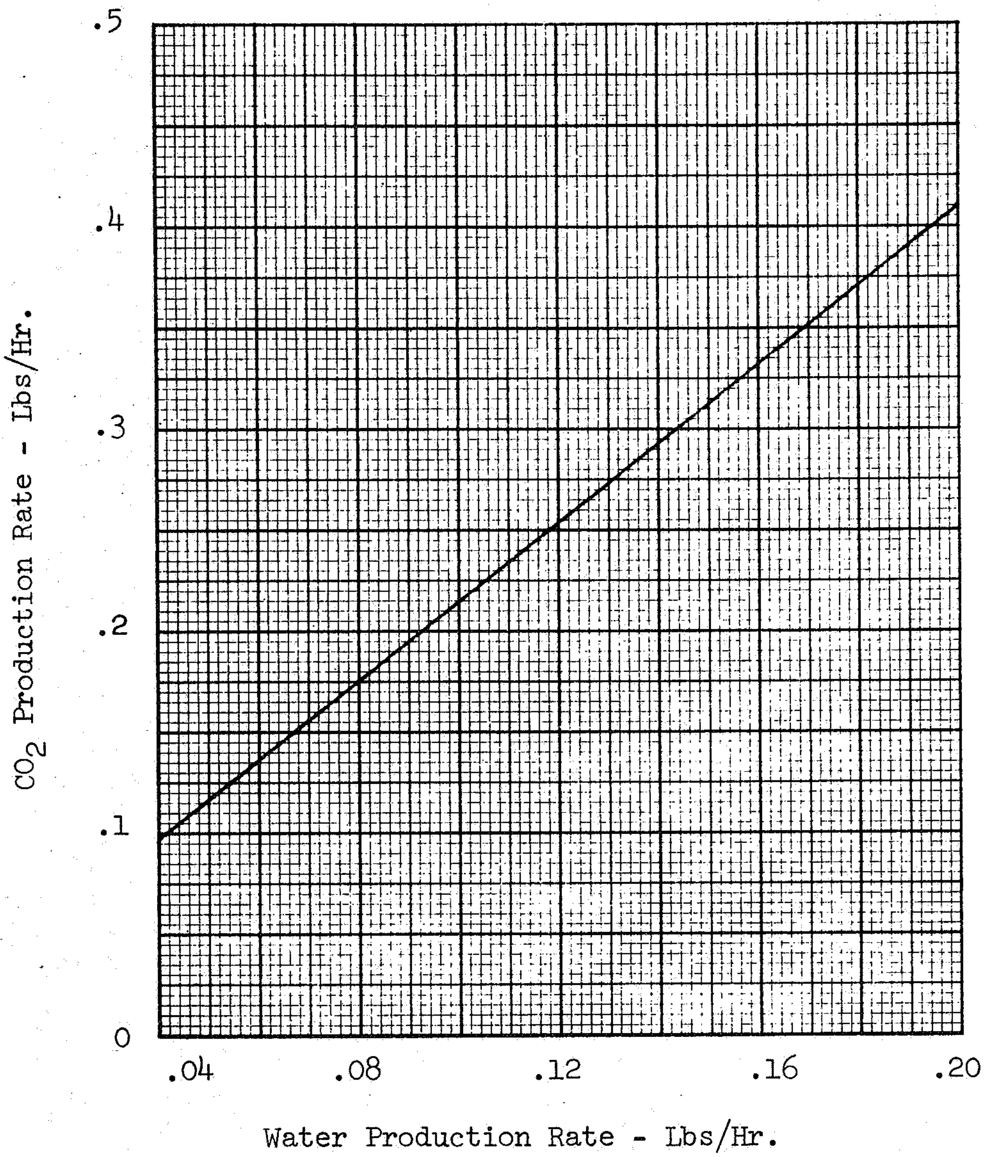


Figure 4.5-31 LiOH-CO_2 Water Production Rate Vs. CO_2 Production Rate

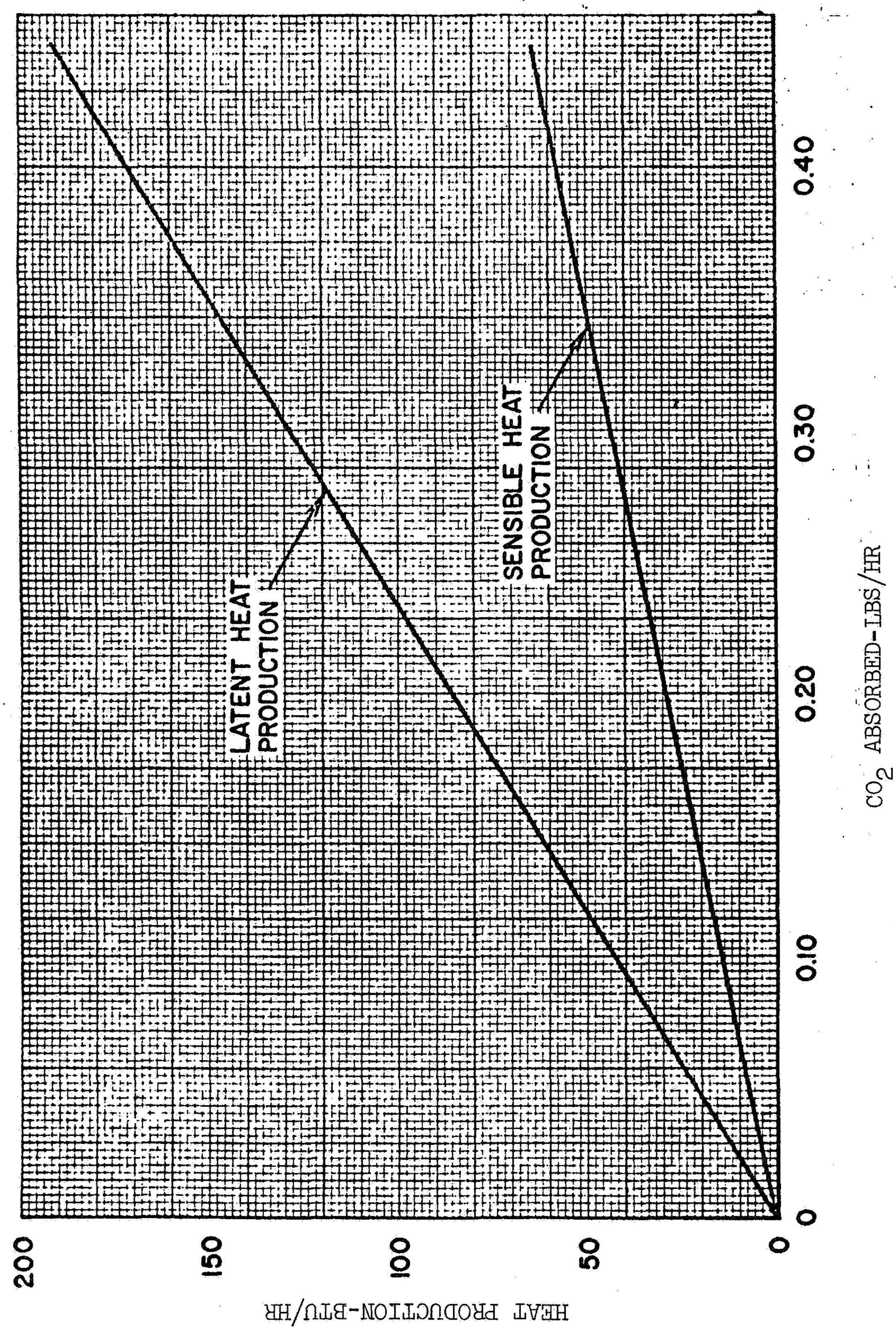


Figure 4.5-32 LiOH Cartridge Heat Production

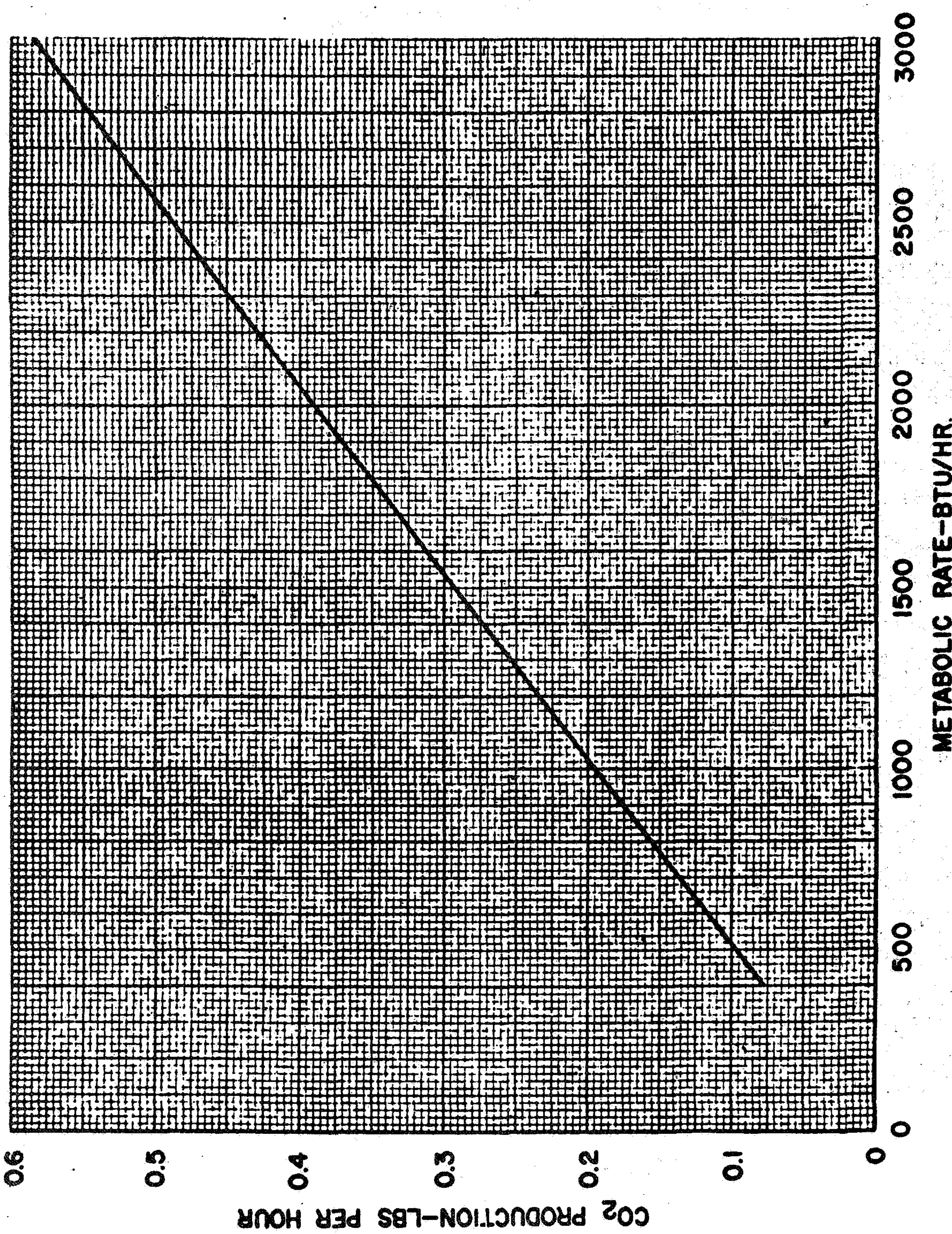


Figure 4.5-33 CO_2 Production Versus Metabolic Rate

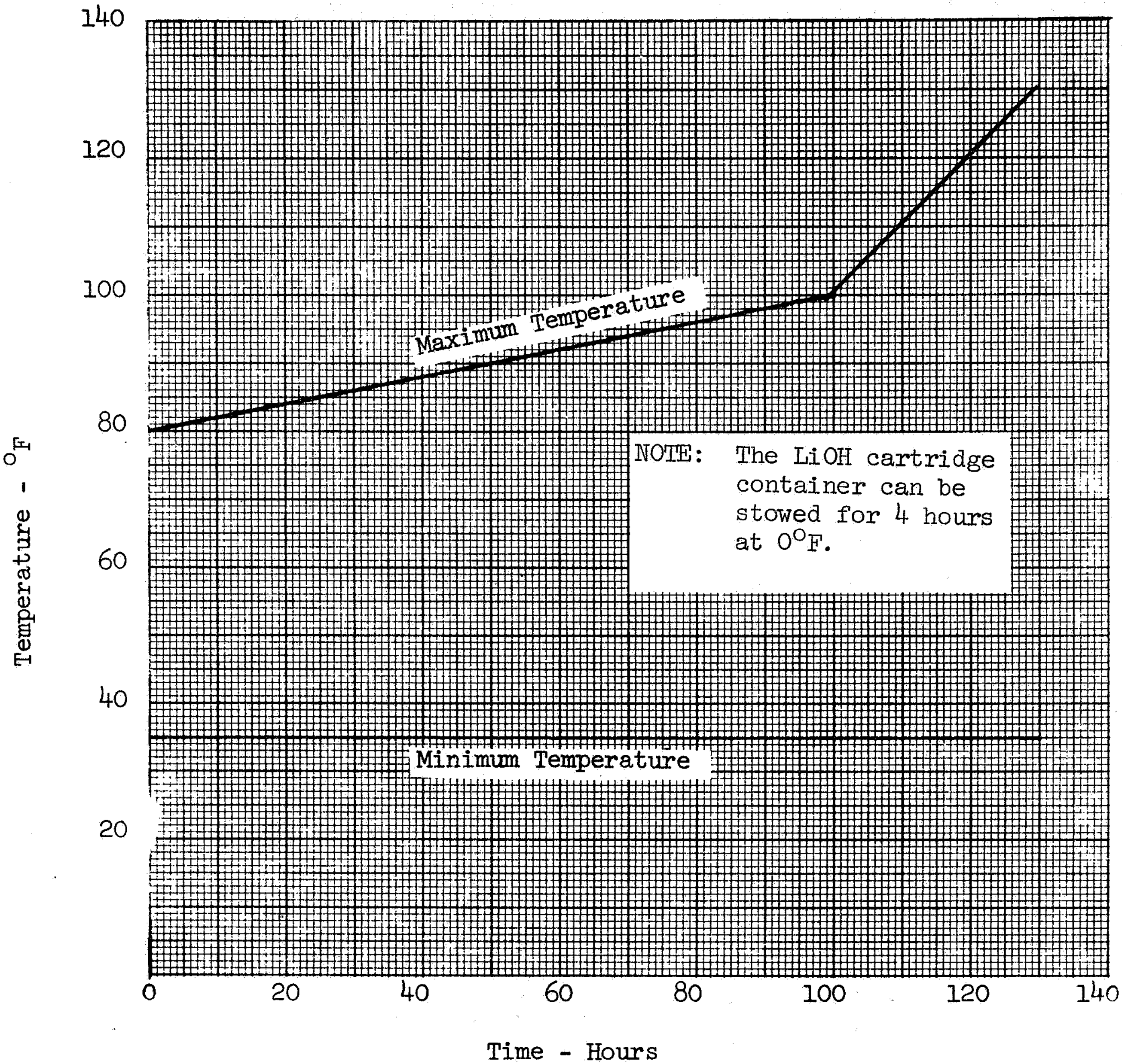


Figure 4.5-34 Allowable Time/Temperature Envelope for LiOH Storage

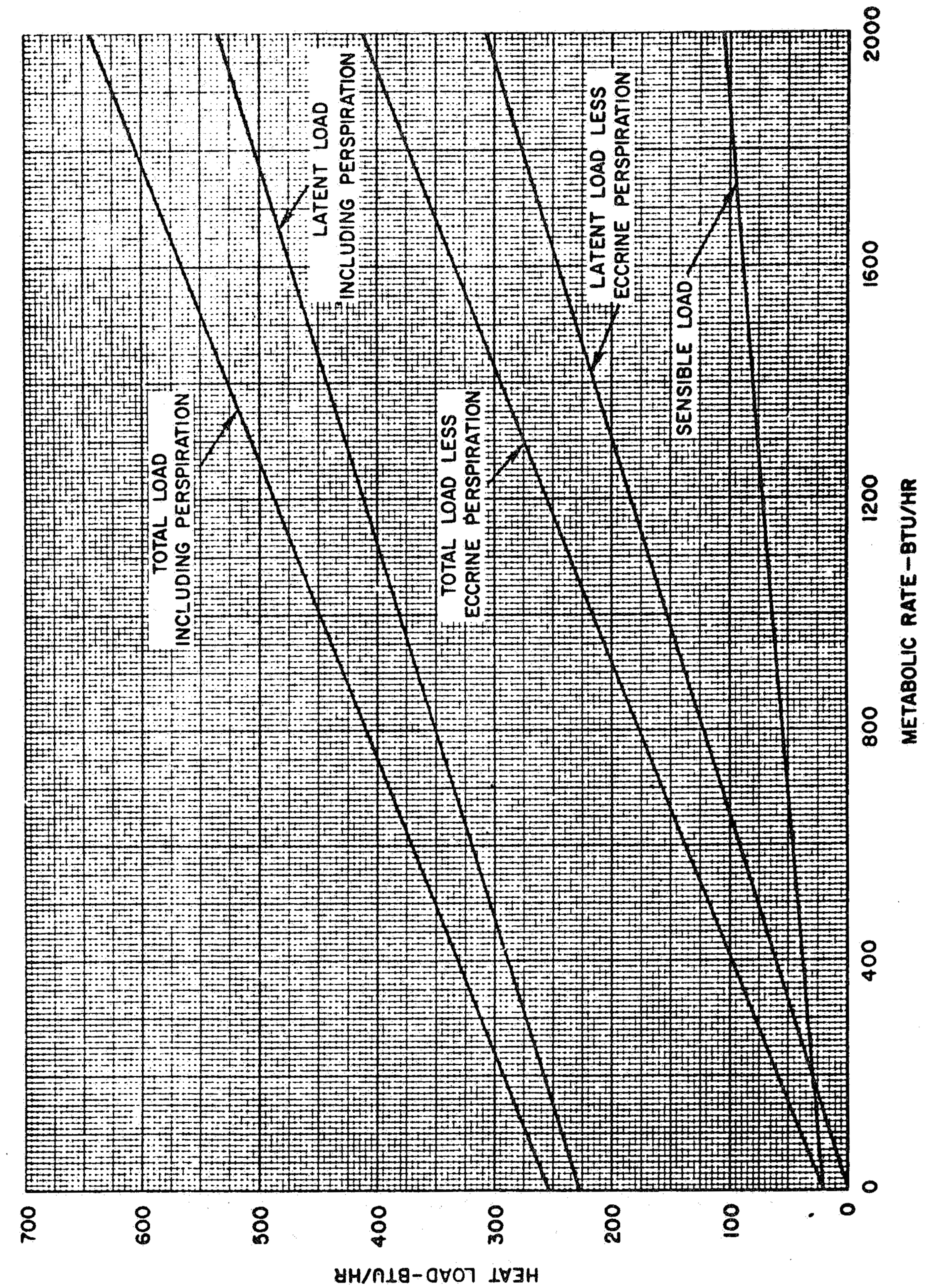


Figure 4.5-35 Ventilation Loop Sublimator Heat Loads Versus Metabolic Rate

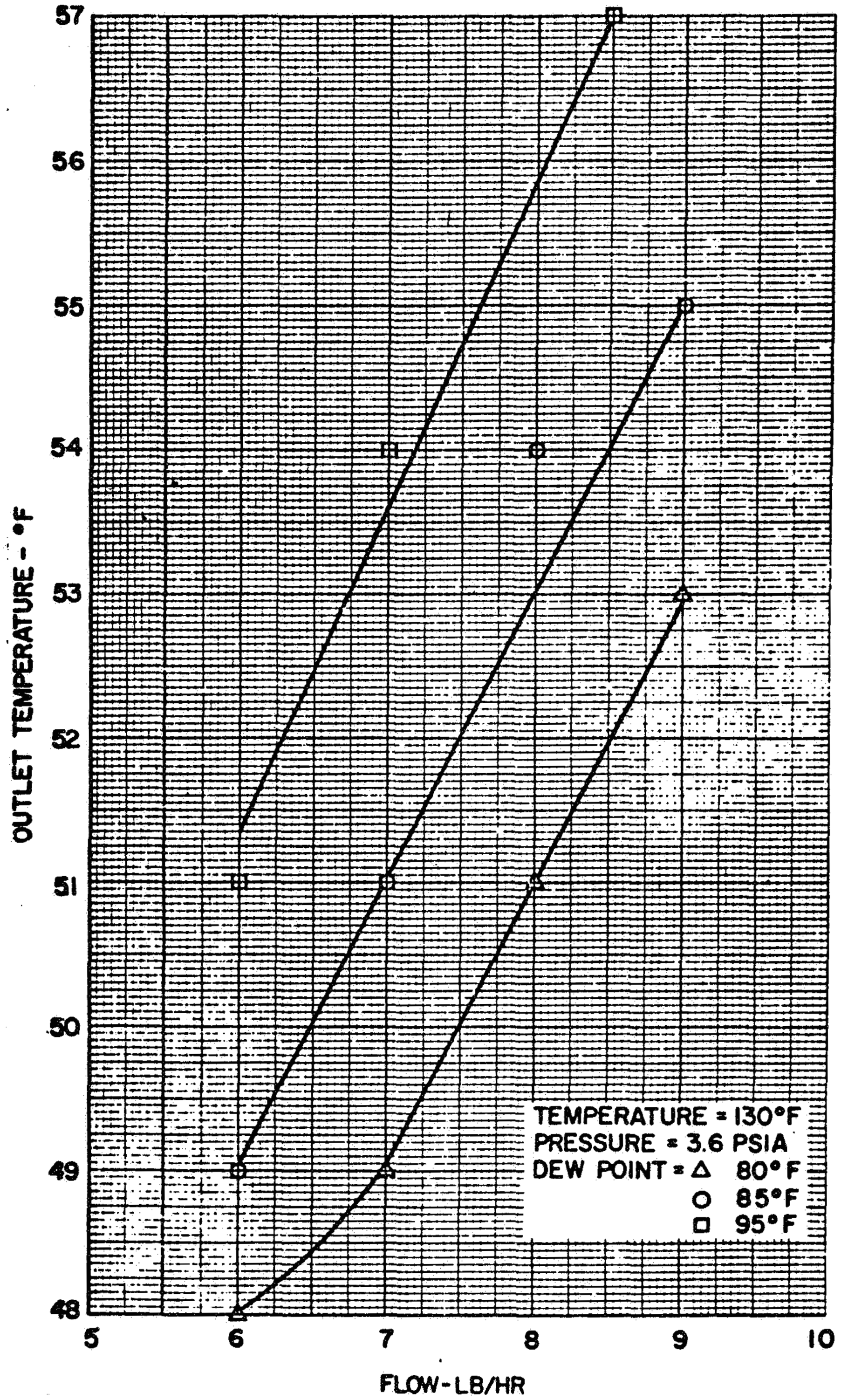


Figure 4.5-36 Sublimator Outlet Temperature Versus Flow Rate

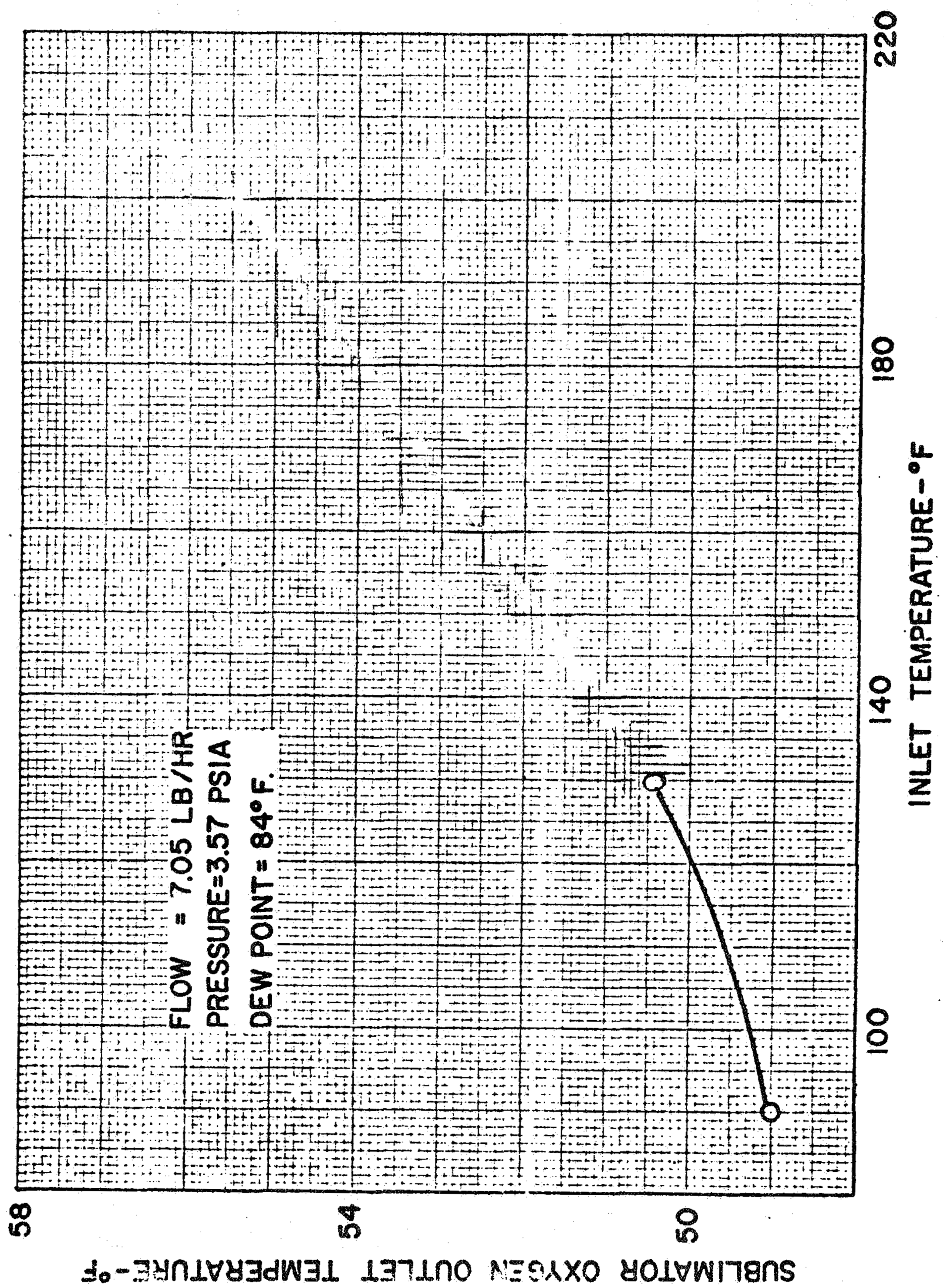


Figure 4.5-37 Sublimator Oxygen Outlet Temperature Versus Inlet Temperature

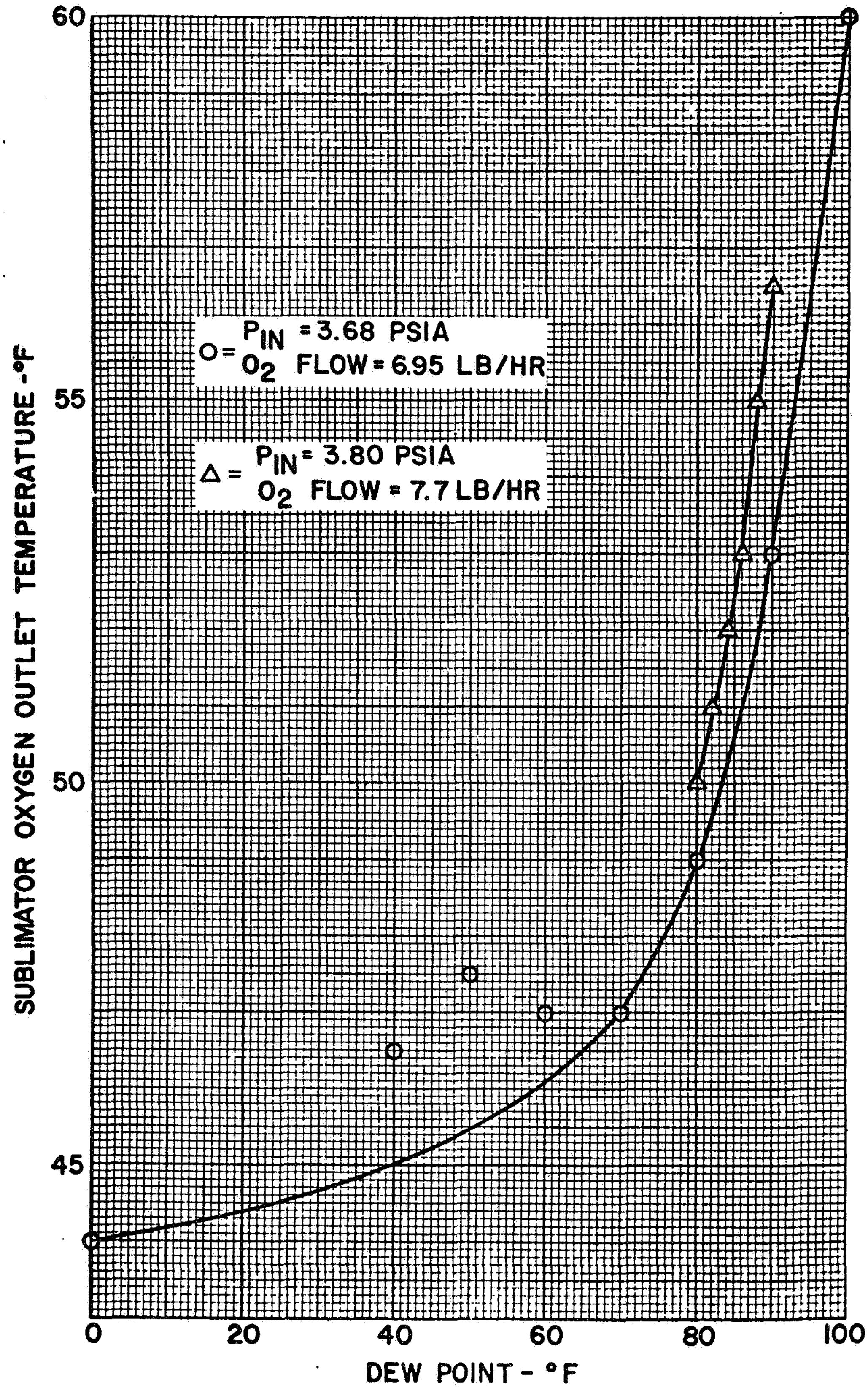


Figure 4.5-38 Sublimator Oxygen Outlet Temperature Versus Inlet Dew Point

4.5.4 Liquid Transport Loop

The PLSS liquid transport circuit pressure rise and flow characteristics are shown in Figure 4.5-39.

4.5.4.1 Pump

Figure 4.5-40 shows the pressure rise/flow characteristics of the PLSS pump and corresponding power consumptions.

4.5.4.2 Liquid Transport Circuit Sublimator

The heat load applied to the sublimator as a function of metabolic load and ambient conditions is shown in Figure 4.5-41.

Liquid transport loop sublimator performance data is provided in Figure 4.5-42.

4.5.4.3 Diverter Valve

The diverter valve controls the water temperature by causing the recirculatory water to bypass the sublimator. The valve design prevents deadheading the pump. The flow splits of the diverter valve are shown in Table 4.5-10.

4.5.4.4 Restricted Flow

With the diverter valve in minimum cooling, and with little or no air in the system, sublimator flow ceases at a water loop flow of 1.2 to 1.4 lbs/min. With the diverter valve in intermediate cooling, sublimator flow will continue down to a water loop flow of 1.0 lb/min. (Flows belows 1.0 lb/min. have not been checked).

4.5.4.5 Gas Separator

The gas separator functions to remove free gas from the LCG and PLSS transport water loop. Free gas may be evolved within the LCG thru use with the LM 192 or may come from leakage while stowed. Evaluation data of the LM 192 liquid loop showed 5 to 14 cc of evolved gas. Data on LCG leakage during stowage may be found in paragraph 4.2.1 of this book. The Free gas removed by the gas separator is stored in the gas separator houseing until manually vented. Venting is normally accomplished in the pressurized LM cabin during PLSS recharge. Limitations on venting during EVA are noted in PLS-23, paragraph 3.4 of this book. The design criteria for the gas separator requires a collection capacity of 30 actual cubic centimeters minimum. Data indicates that in excess of 37 acc's may be collected prior to breakthrough. The characteristic

4.5.4.5 Gas Separator (cont'd)

flow rates for venting of oxygen, water vapor and water from the separator are provided in Figures 4.5-43 and 4.5-43.1.

4.5.4.6 Operating Pressure

A) The possible operating pressure range for lunar surface EVA is 4 to 21 psia.

B) The expected operating pressure at the start of the first EVA is 17.0 psia to 19.5 psia based on the following conditions:

(1) The PLSS is charged from the ground facility with water at a pressure 1.0 to 3.0 psi above sea level pressure within T-76 to T-72 hours (T=0 for launch).

(2) EVA 1 is at T + 110 hours

(3) LM environment is uncontrolled after initial pressurization to 5 psia in earth orbit. Cabin temperature increases in accordance with ICD upper limit.

(4) Prior to interfacing with the PLSS, the LCG is operating on the LM 192 system which results in an LCG pressure of 18 to 20 psia (based on a full accumulator in the LM-192 and the LM-192 system pressure decay associated with the interface of both LCG's).

Note: The most significant effect on the actual PLSS/LCG operating pressure is the pressure of the LCG just prior to interface with the PLSS (i.e. pressure retained from the LM-192 system). Test data indicates that the resultant PLSS/LCG operating pressure is 80% LCG pressure and 20% PLSS pressure.

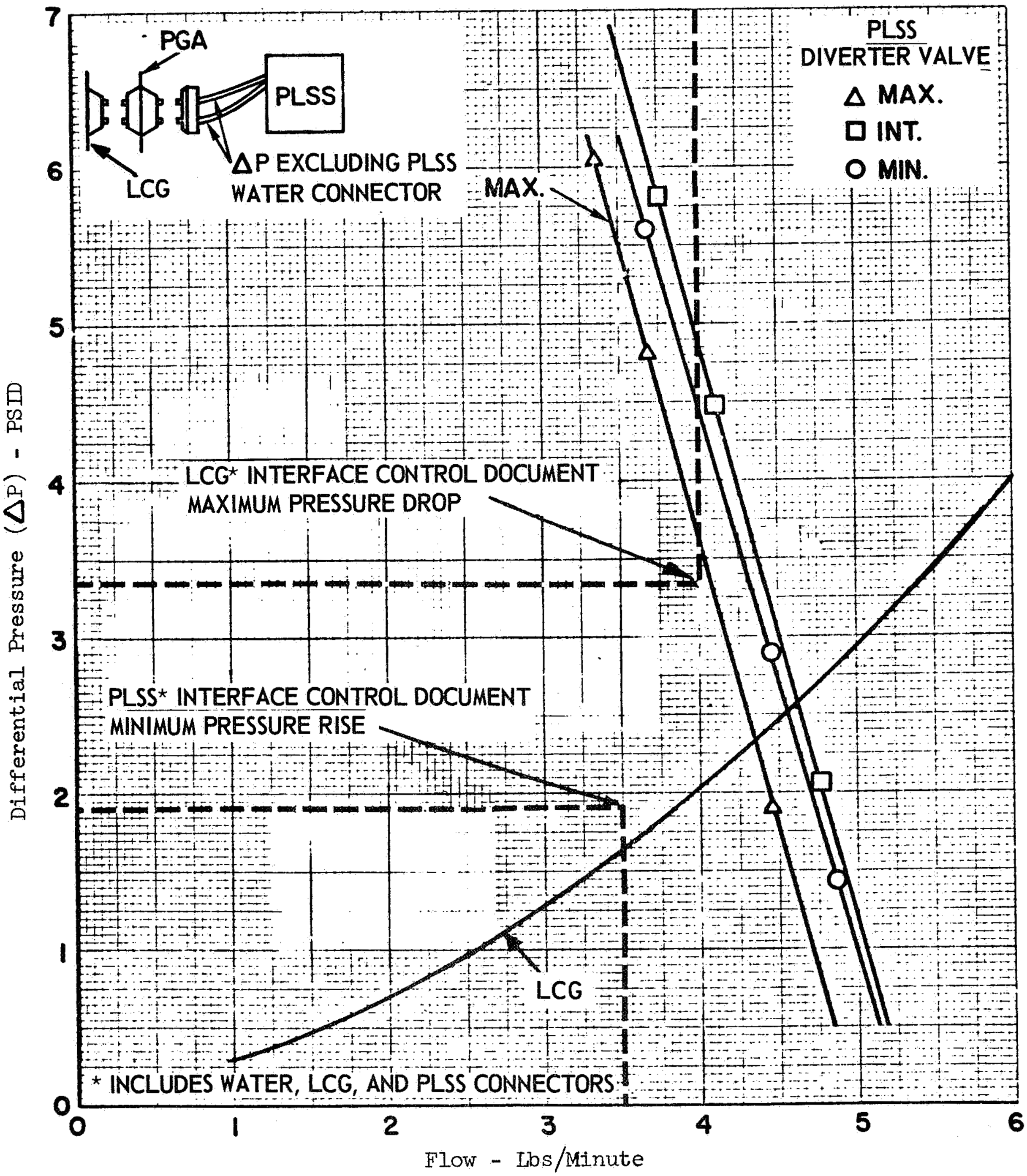


Figure 4.5-39 PLSS Transport Water Loop ΔP Versus Flow

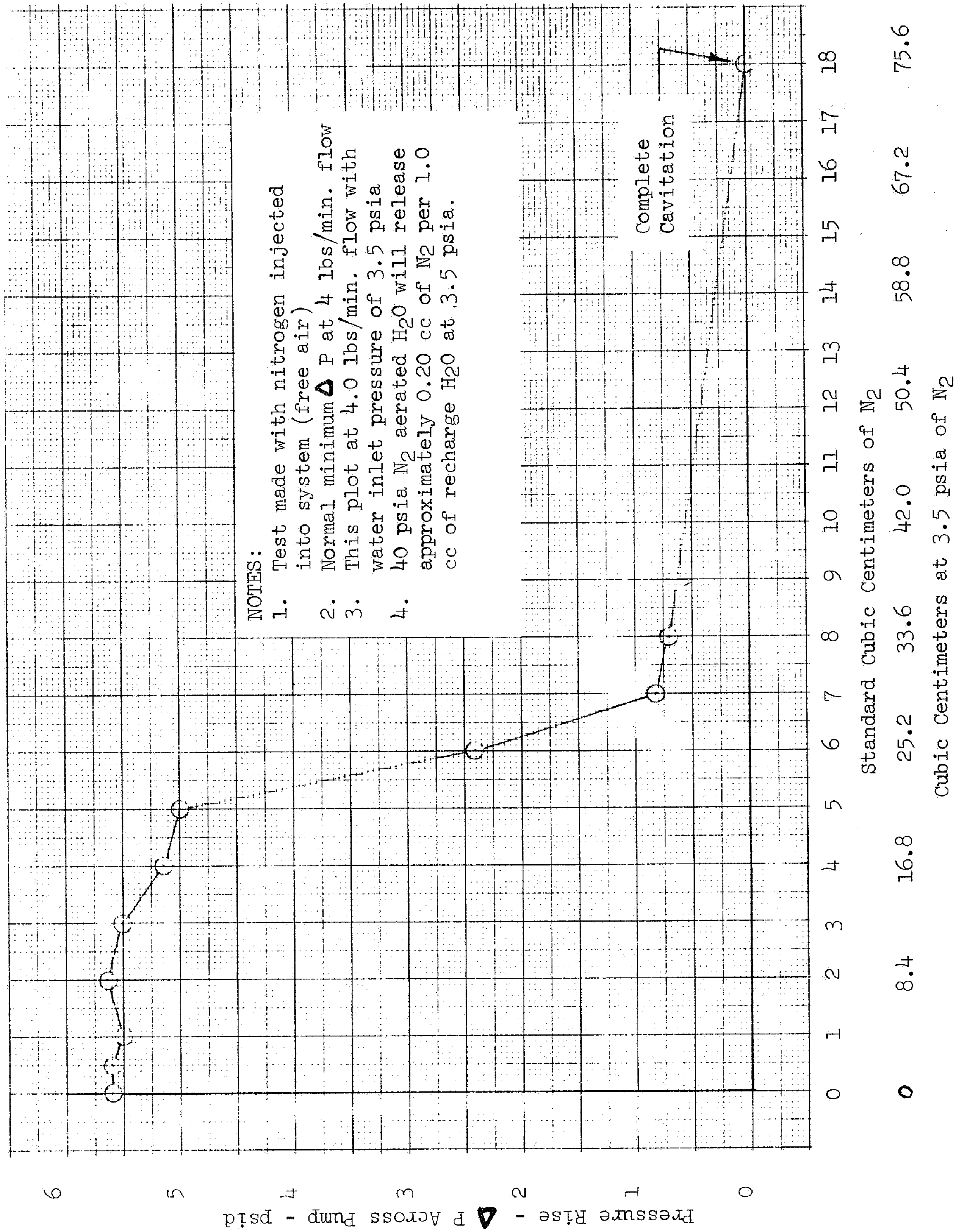


Figure 4.5-39.1 Pump Degradation and Cavitation (Pump Pressure Rise) Versus Transport Water Aeration (Volume of Injected Gas)

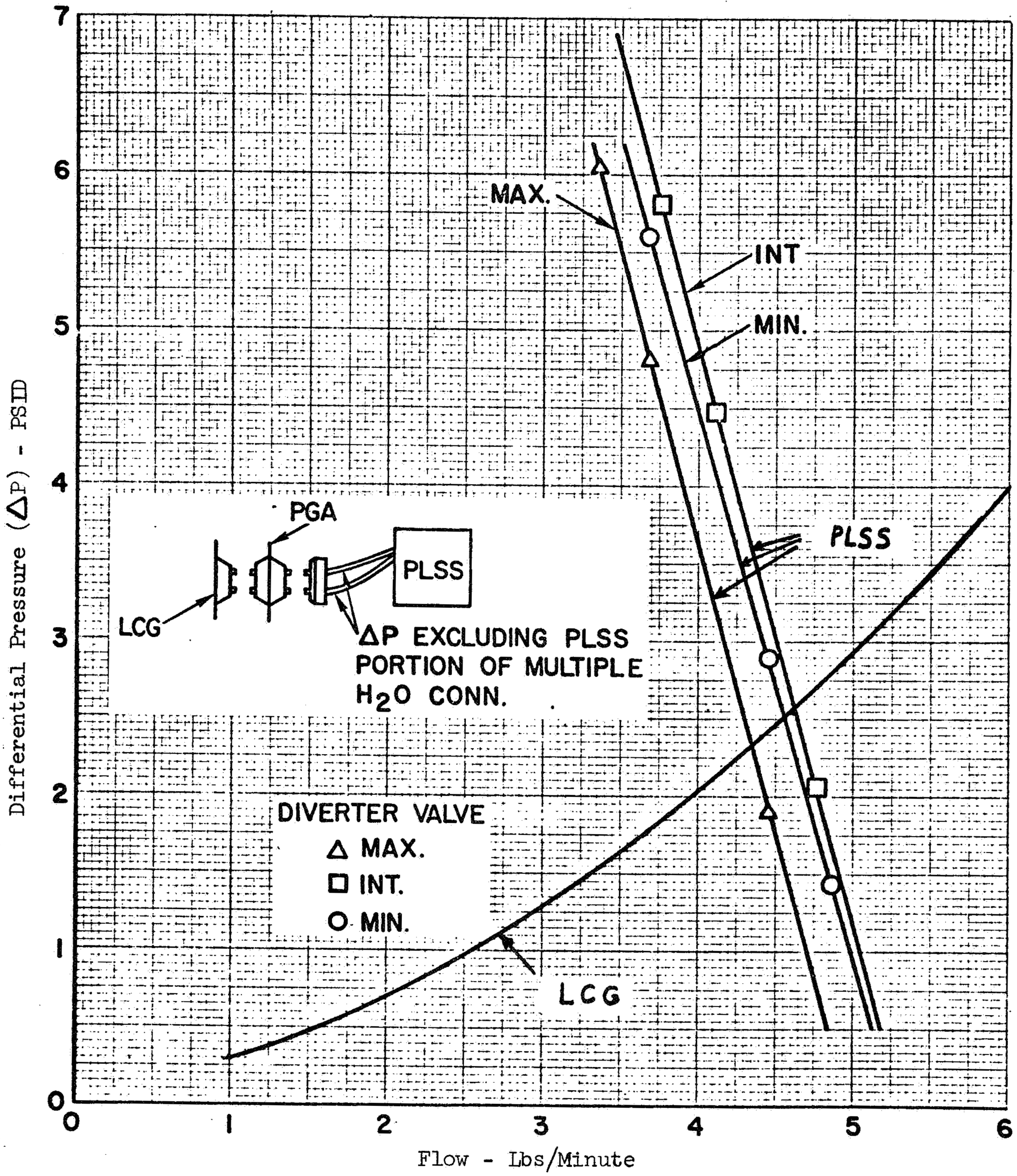


Figure 4.5-39 PLSS Transport Water Loop Δ P Versus Flow

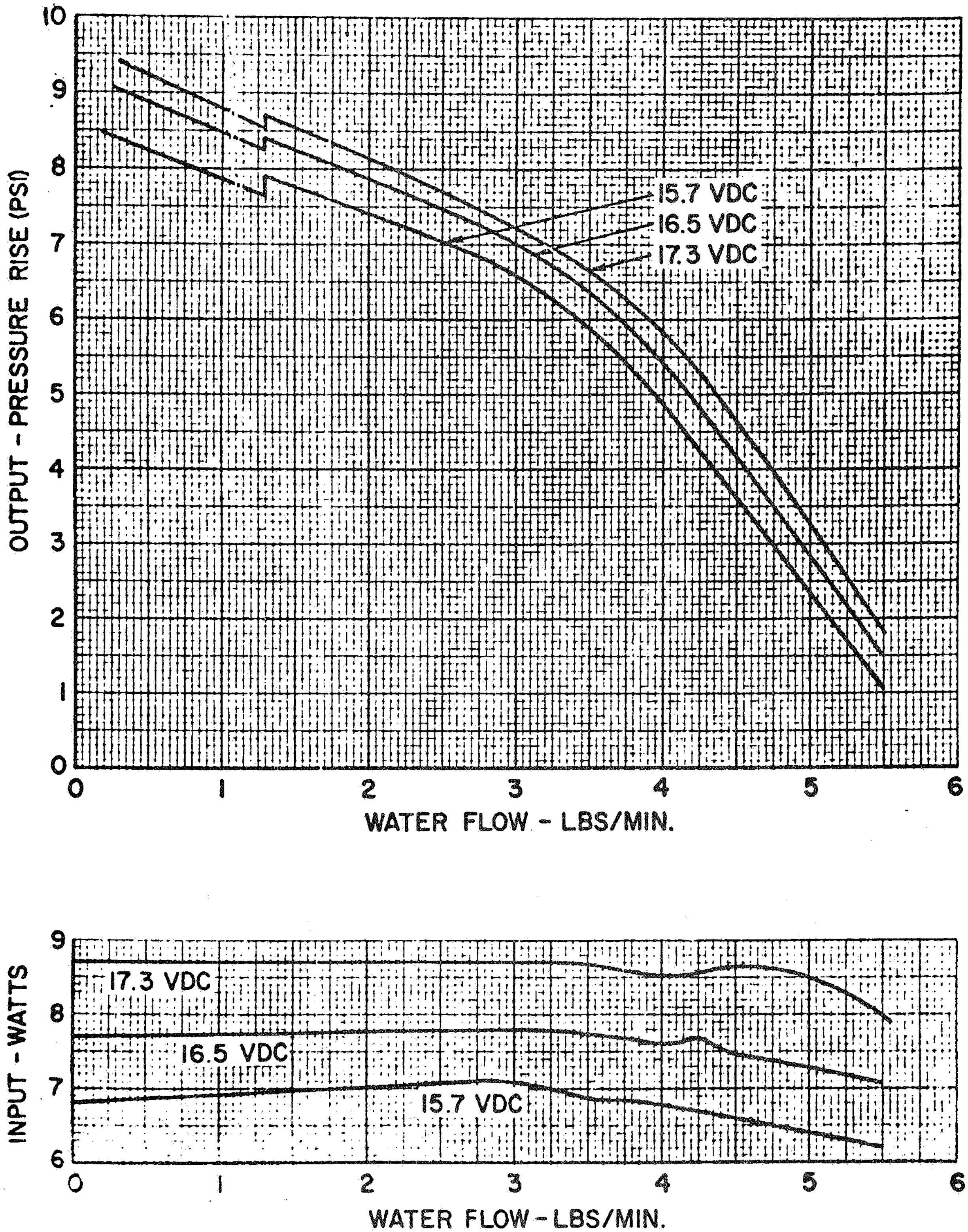


Figure 4.5-40 Water Flow Versus Power Input and Pressure Rise

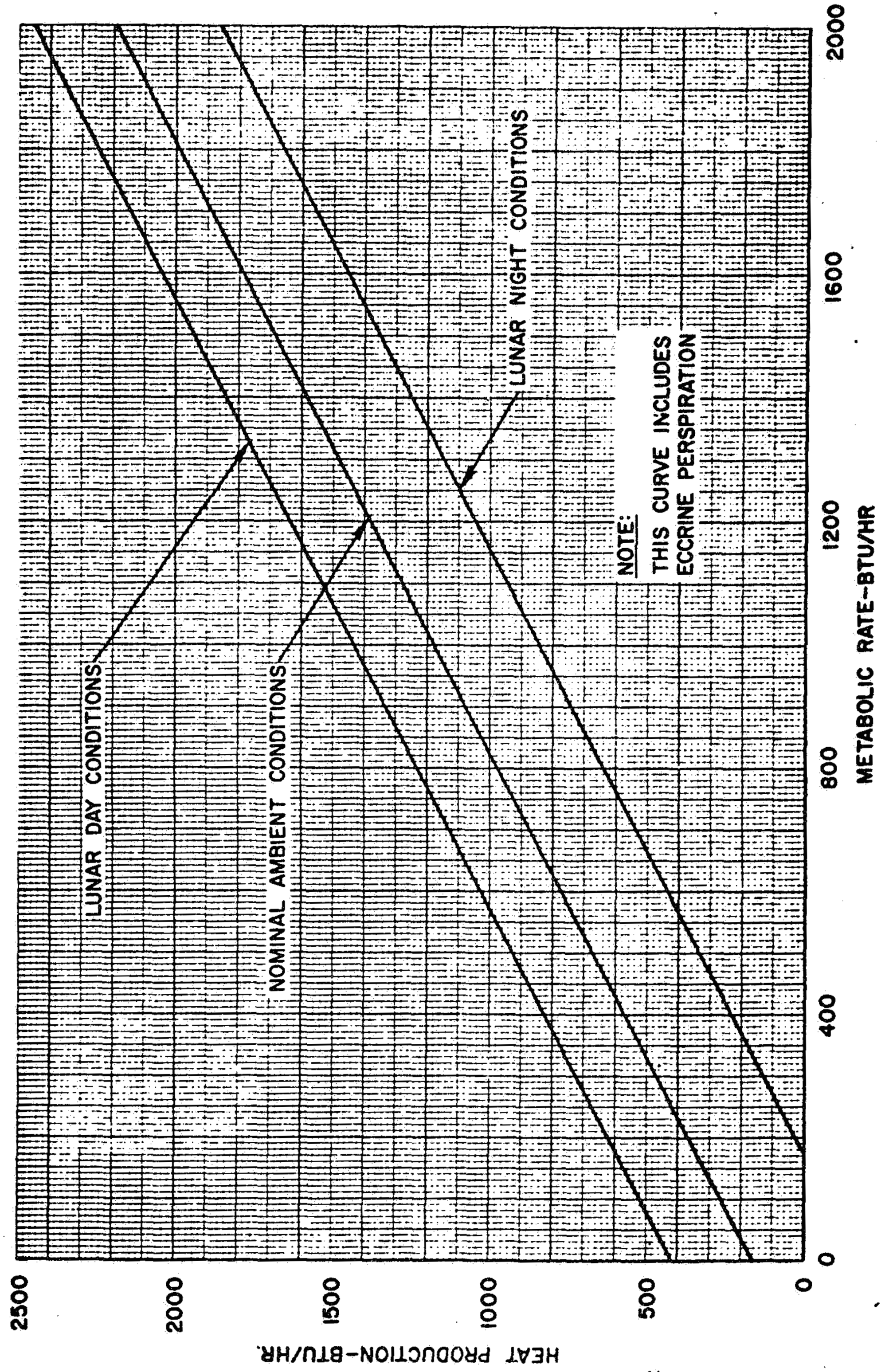


Figure 4.5-41 Liquid Transport Loop Sublimator Heat Loads Versus Metabolic Rate and Ambient Conditions

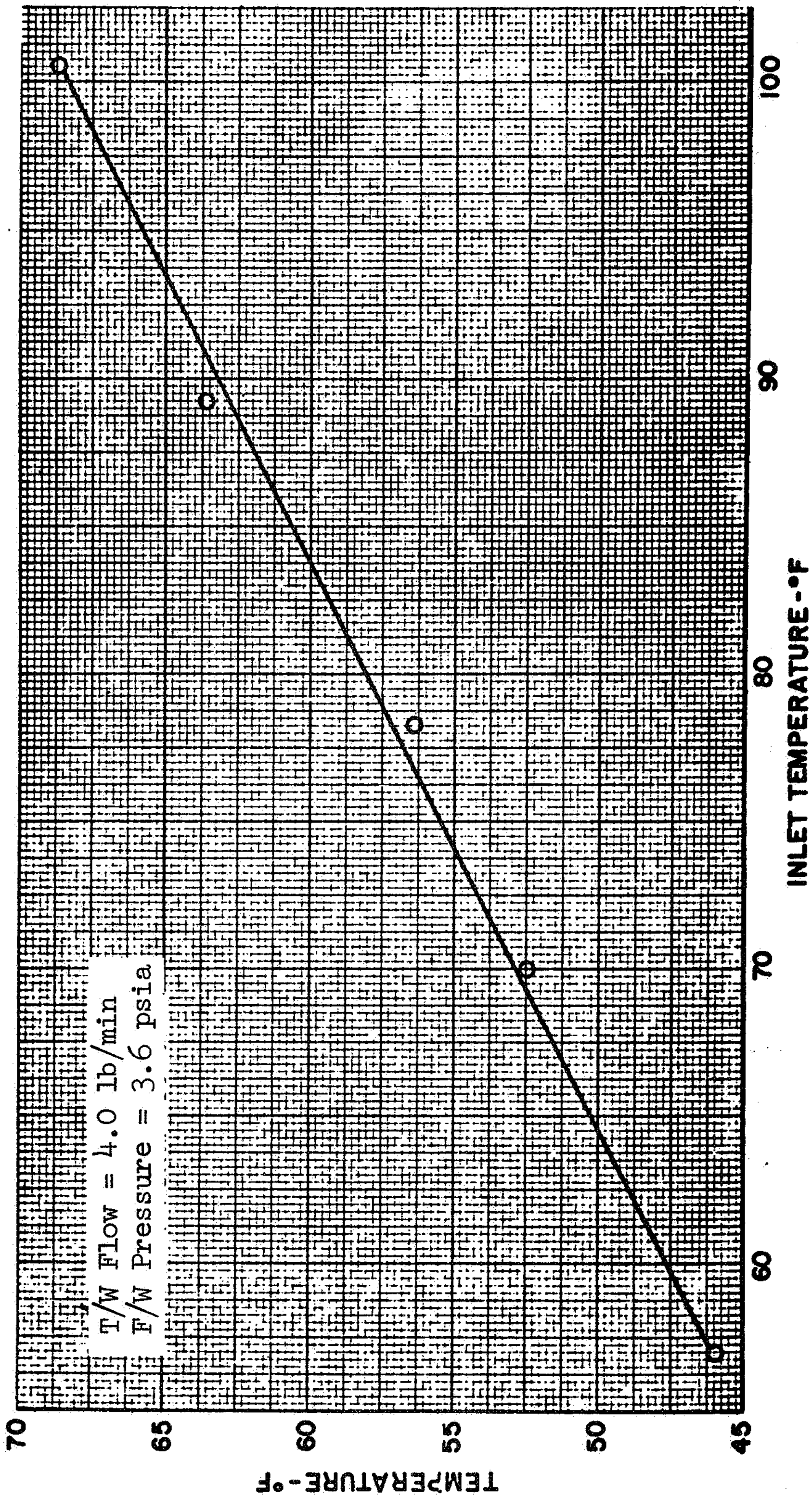


Figure 4.5-42 Sublimator Transport Water Inlet Temperature Versus Outlet Temperature

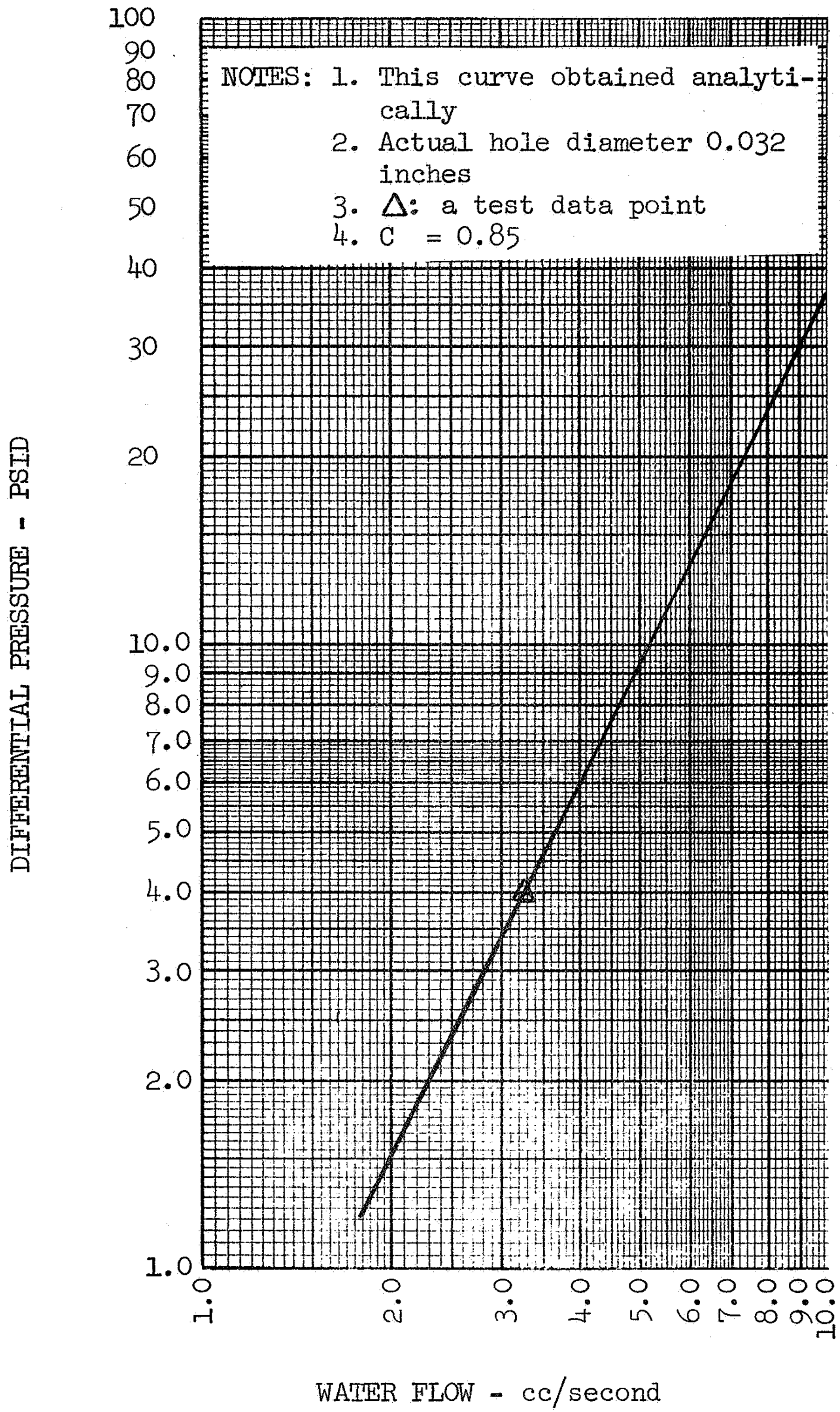


Figure 4.5-43 Transport Water Gas Separator Water Bleed Flow Versus Differential Pressure

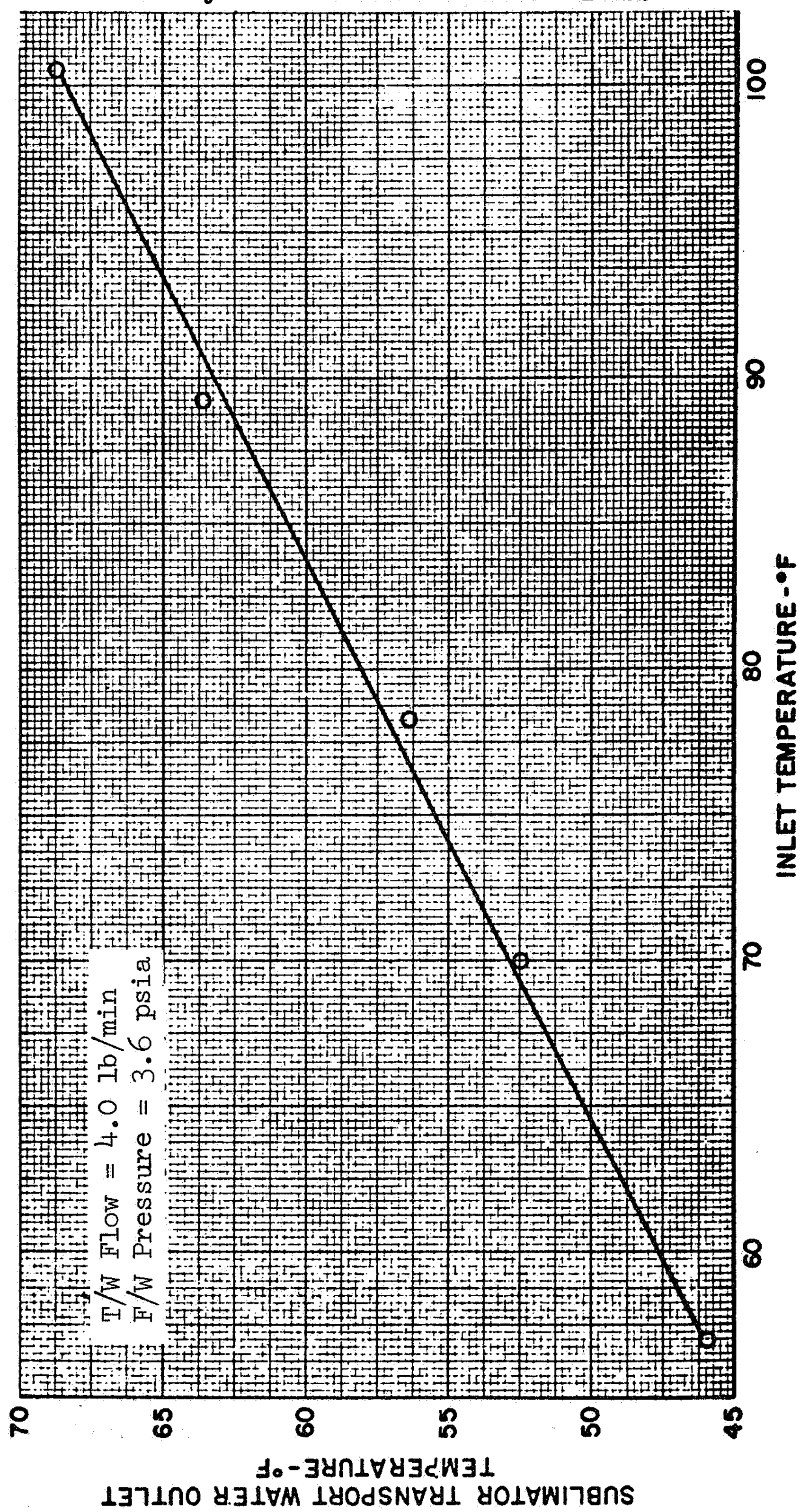
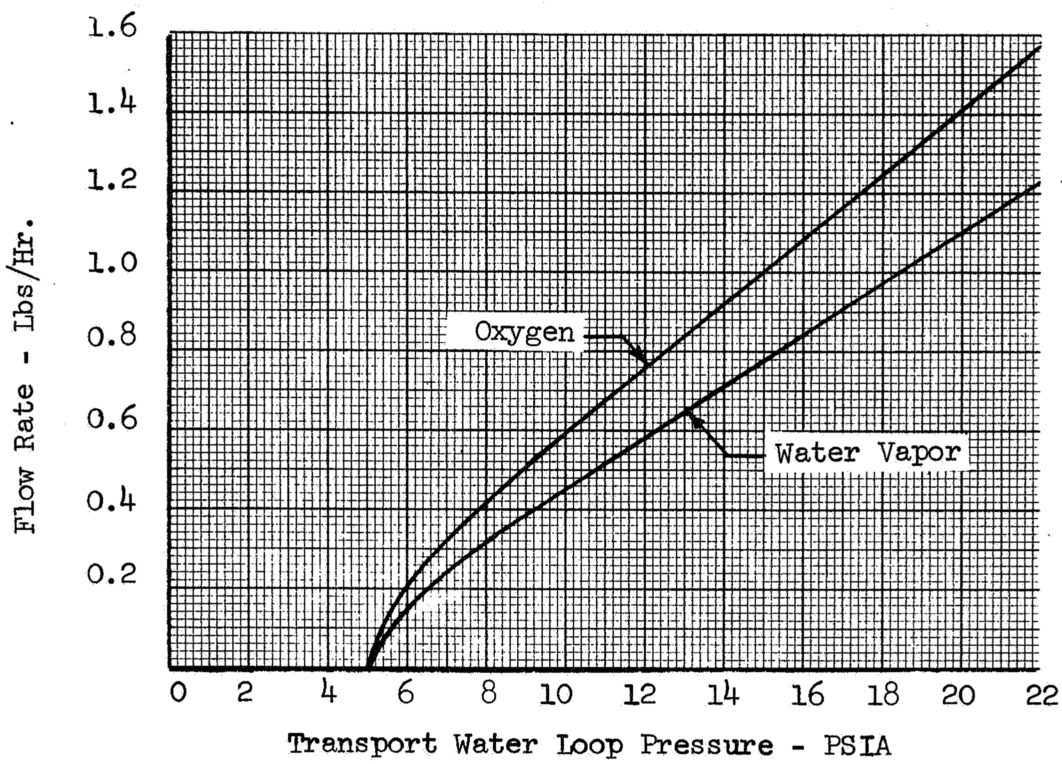


Figure 4.5-42 Sublimator Transport Water Inlet Temperature Versus Outlet Temperature

TBD

Figure 4.5-43 LCG Inlet Temperature Versus Metabolic Rate



NOTE:
1. This curve obtained analytically for gas or water vapor flow at 70°F.
2. Actual hole diameter is 0.032 inches.
3. Ambient pressure is 5.0 psia.
4. $C_f = 0.65$

Figure 4.5-43.1 Transport Water Gas Separator Gas Bleed Flow Vs. Transport Water Loop Pressure

Table 4.5-10 Diverter Valve Flows

VALVE POSITION	NOMINAL FLOW RATES - LB/MIN.		
	TO LCG	FROM BYPASS	FROM SUBLIMATOR
Max.	4.0	0	4.0
Int.	4.0	3.50	0.50
Min.	4.0	3.86	0.14

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4.5.5 Feedwater Supply Loop

The PLSS feedwater system supplies the expendable water to the sublimator where it freezes and sublimes to the vacuum environment in which the EMU is operating. The cooling resulting from the sublimation is used to dissipate the heat generated within the EMU and the heat entering the EMU. These heat loads are given in Figure 4.5-44 and the feedwater usage rate versus heat load is given in Figure 4.5-45. An orifice restricting the flow of feedwater is located between the sublimator and the feedwater shut-off valve. The flow characteristics of this orifice are presented in Figure 4.5-46.

Feedwater pressure at the entrance to the sublimator is monitored by a single transducer. This transducer provides a signal for telemetry readout of the pressure via the EVCS and also provides a signal to the EMU Warning System described in paragraph 4.5.1.5. The low feedwater pressure warning is initiated when the pressure falls below 1.30 to 1.60 psia. This corresponds to a water quantity of approximately 0.6 pounds downstream of the feedwater shut off valve assuming the system is operating normally. The feedwater pressure readout from telemetry and the low feedwater warning switch provide verification of sublimator startup and sublimator operation as well as feedwater depletion. The sublimator has demonstrated "start up" capability at vent loop pressures of 6.0 psia. The pressure of the feedwater is shown in Figure 4.5-47. Figure 4.5-47.1 illustrates this same pressure at sublimator shutdown.

Sublimator operating characteristics through feedwater depletion and beyond for a metabolic rate of 1200 BTU/Hr and 1600 BTU/Hr are shown in Figures 4.5-48 and 4.5-48.1.

The feedwater reservoir is filled with 8.5 plus pounds of water prior to launch and can be recharged in the LM through the feedwater fill connector. A feedwater fill of 8.5 pounds may not be possible in all cases as this was not a design requirement. There is also a GSE instrument inaccuracy of ± 1 ounce associated with the feedwater fill capacity. The time required to fill the reservoir can be determined from Figure 4.5-49 for a given charging pressure differential. A visual indicator is located in the bladder vent line to give further indication of completion of recharge. The visual indicator is similar to a sight glass. The recharge is complete when the gas bubbles disappear and only feedwater appears in the visual indicator. The flow rate of water through the vent line as a function of pressure differential is shown in Figure 4.5-49.1.

4.5.5 A branch of the feedwater loop is connected to the transport water loop through a check valve. In the event the transport water pressure is reduced by leakage or other malfunction, the feedwater loop will supply makeup water through the one-way check valve. The performance characteristics of the check valve are given in Figure 4.5-50.

After the crewmen ingress the LM subsequent to EVA and the LM cabin is sealed, the water vapor produced as a result of sublimation will increase the LM cabin pressure at a rate described in Figure 4.5-51. Normal sublimator action ceases when the ambient pressure rises above 1000 microns.

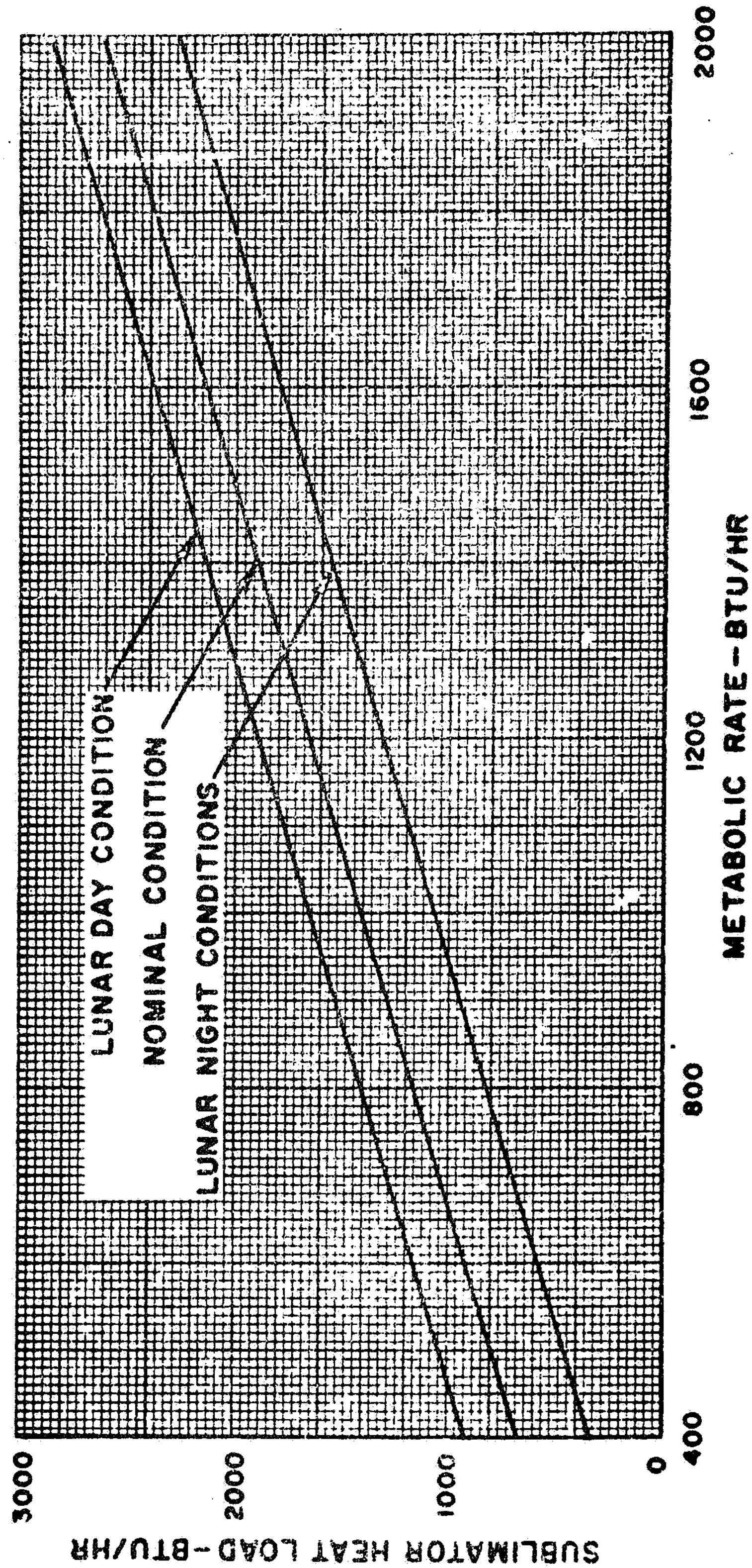

Figure 4.5-44 Sublimator Total Heat Load Versus Metabolic Rate

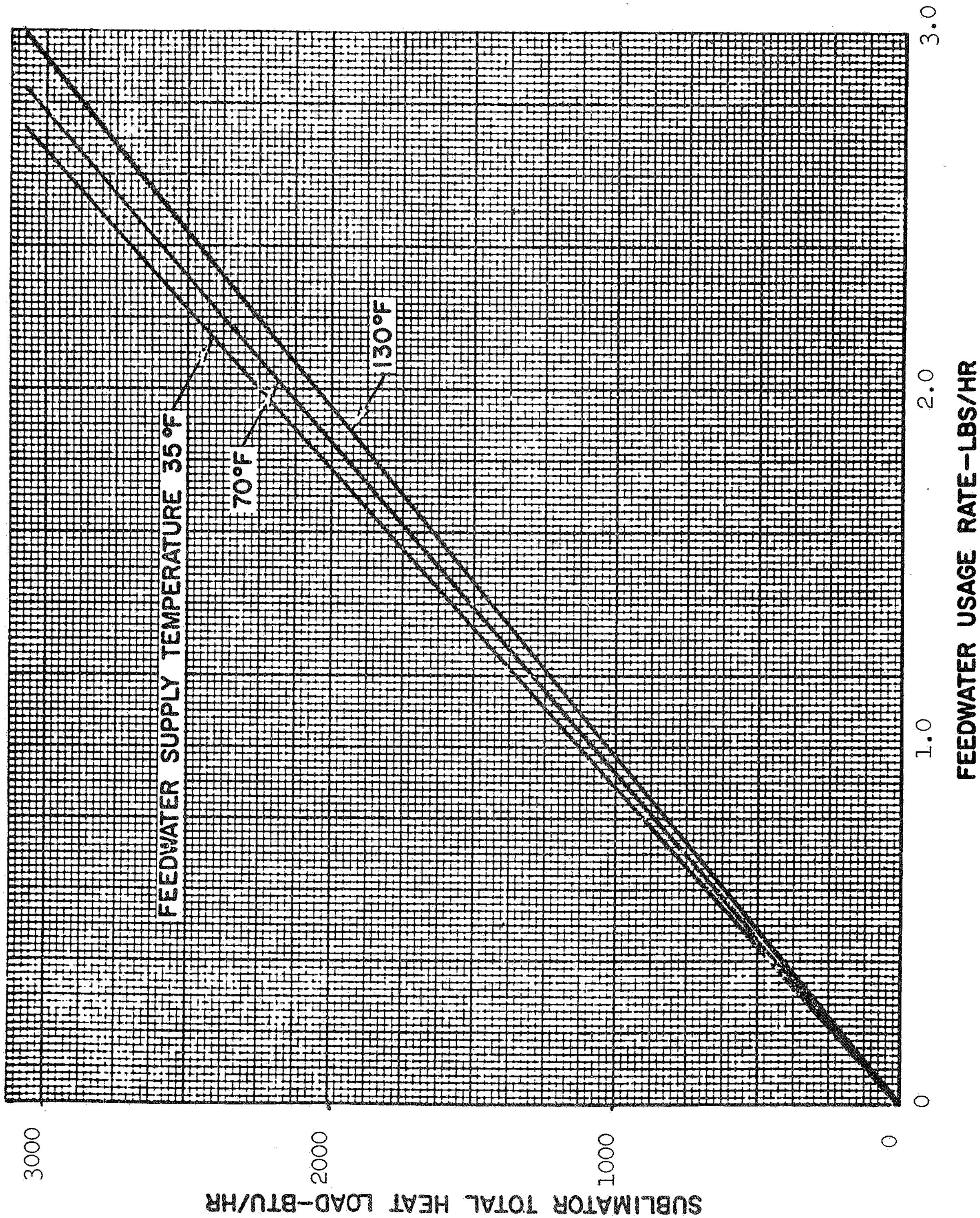

Figure 4.5-45 Sublimator Total Heat Load Versus Feedwater Usage Rate

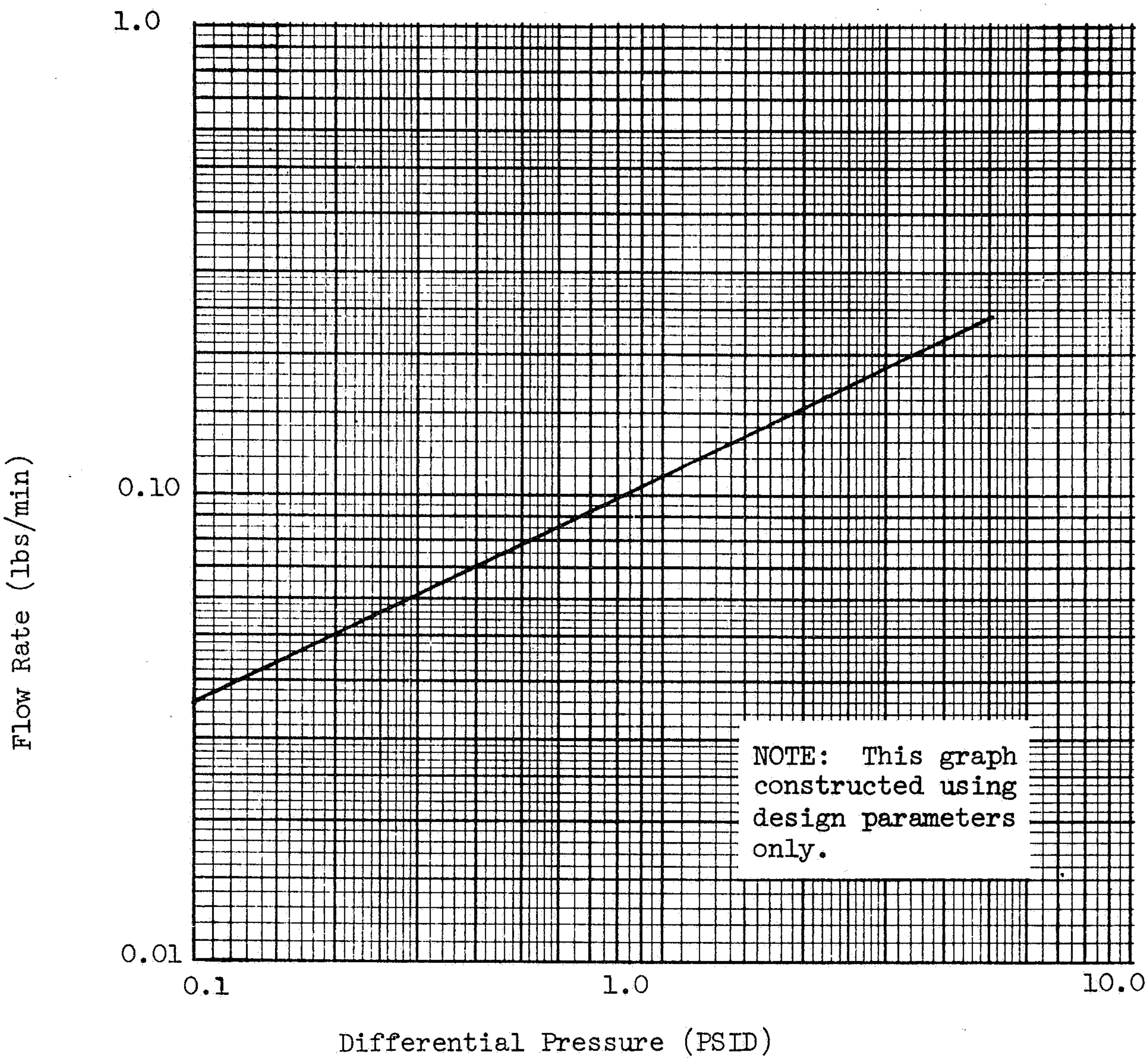

Figure 4.5-46 Sublimator Flow Limiter (Viscojet) Characteristics - Design Parameters

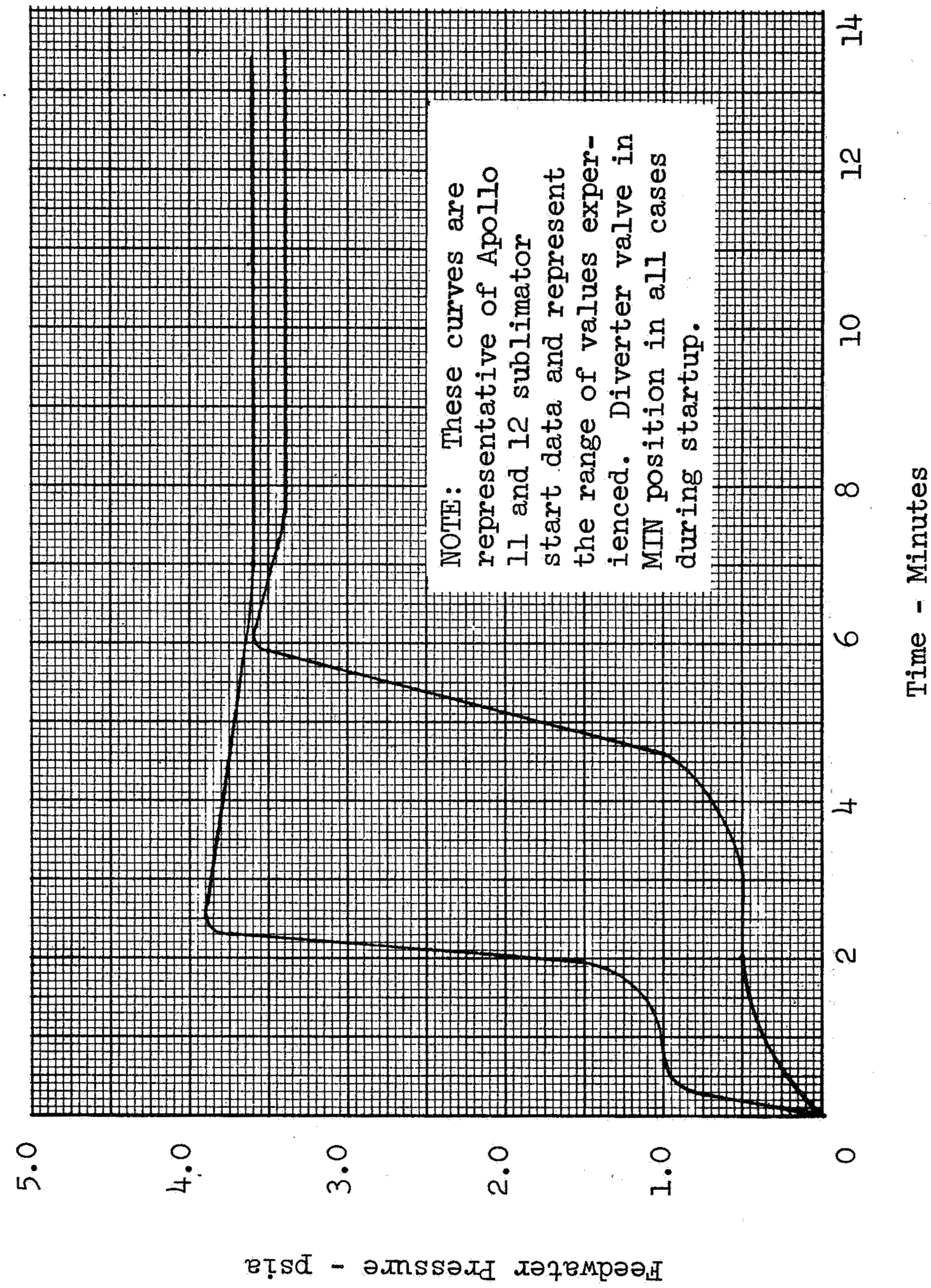

Figure 4.5-47 Feedwater Pressure at Sublimator Versus Starting Time

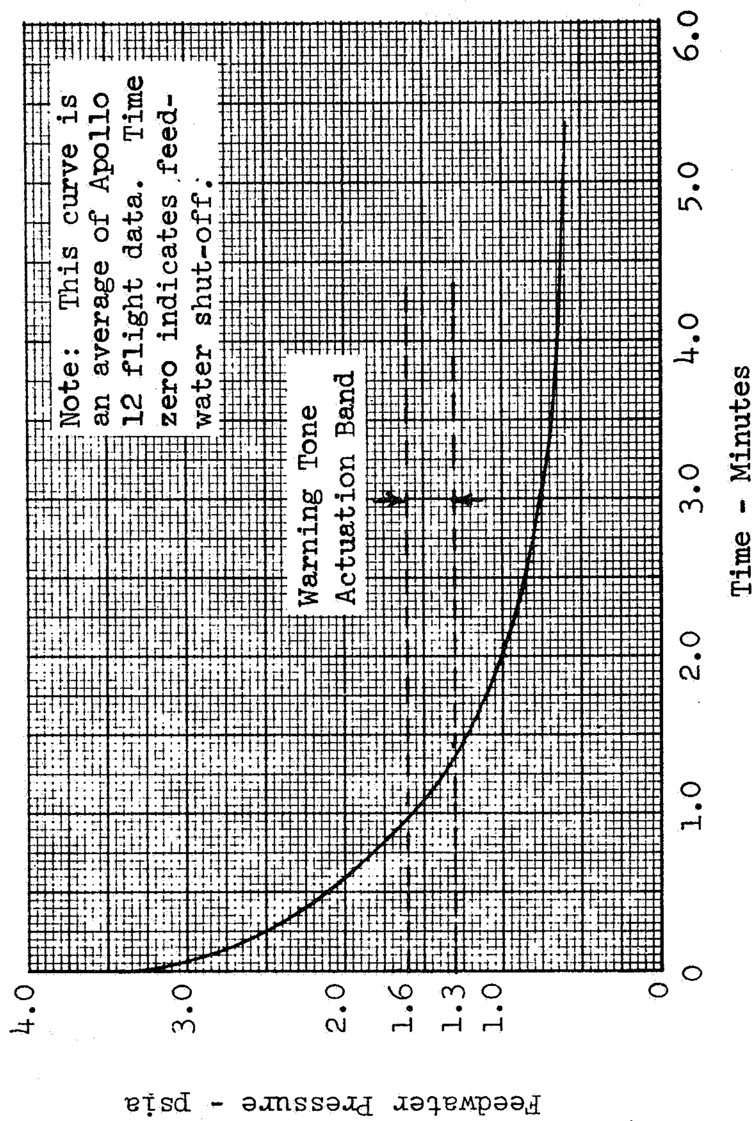

Figure 4.5-47.1 Feedwater Pressure Characteristics at Sublimator Shutdown

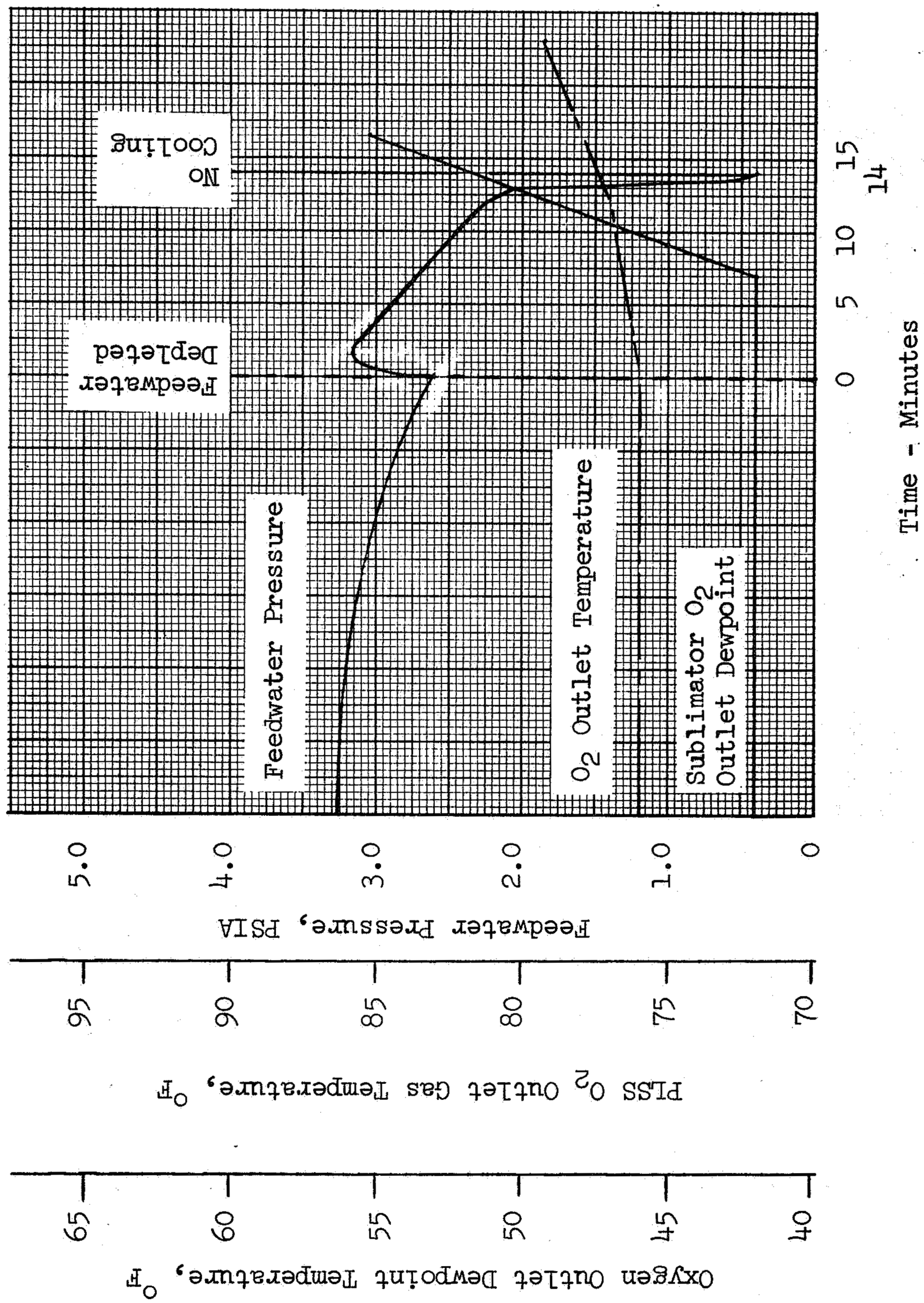

Figure 4.5-48 Feedwater Depletion Characteristics Vs. Time with a 1200 BTU/Hr. Metabolic Load (Max. Diverter Valve Position)

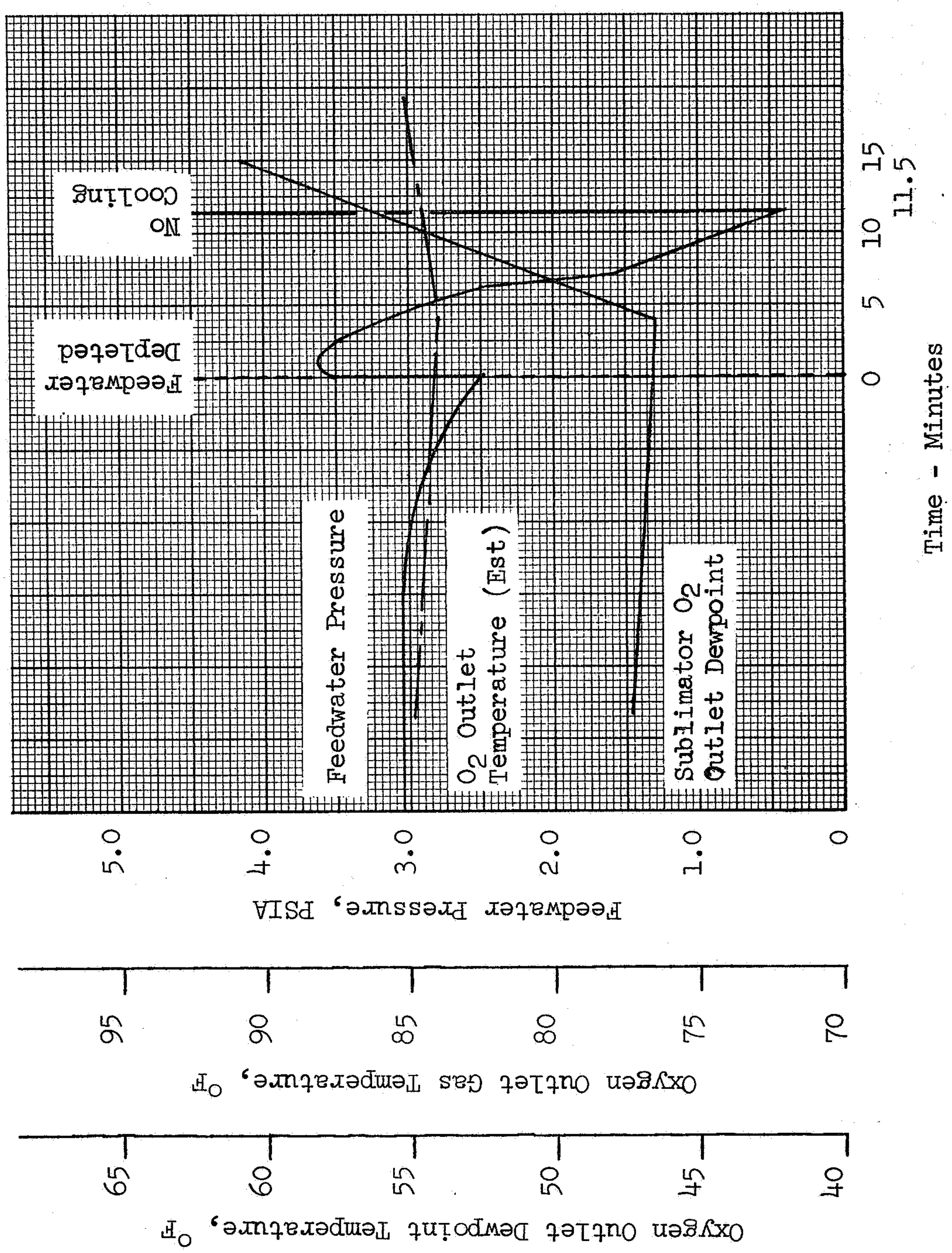

Figure 4.5-48.1 Feedwater Depletion Characteristics Vs. Time with a 1600 BTU/Hr. Metabolic Load (Max. Diverter Valve Position)

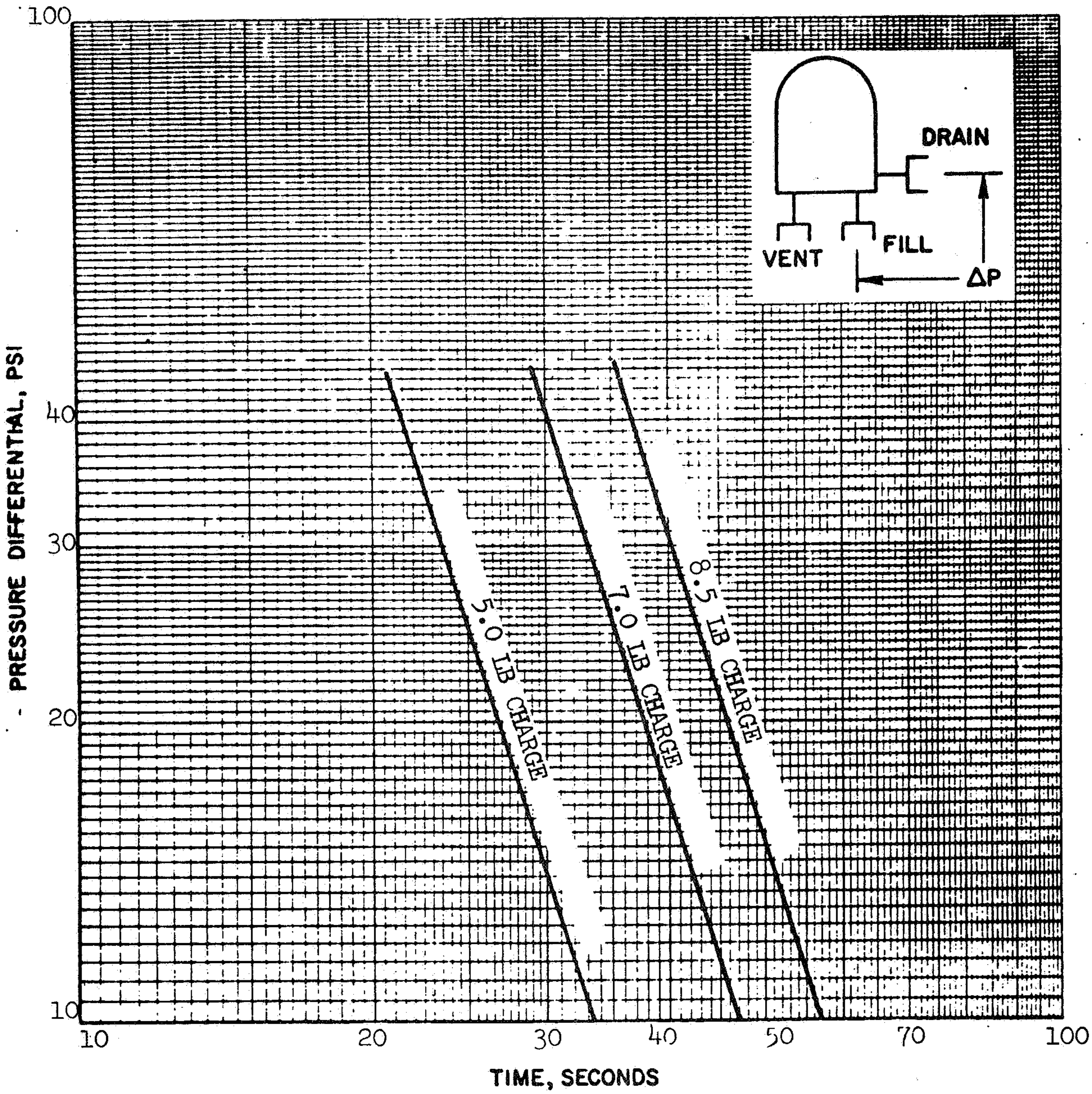

Figure 4.5-49 PLSS Feedwater Reservoir Fill Time Versus Pressure Differential

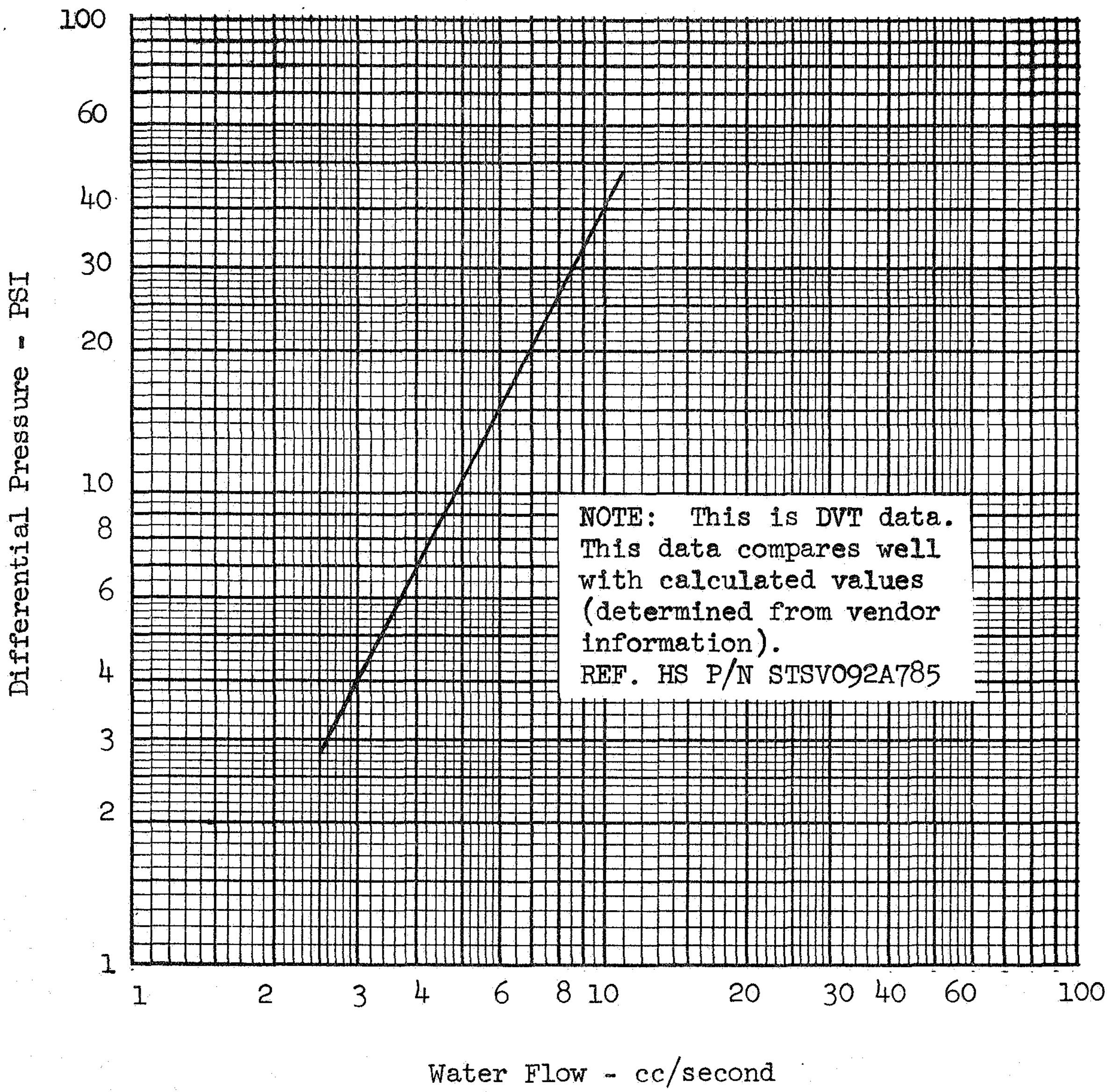

Figure 4.5-49.1 Feedwater Vent System Flow Restrictor Characteristics

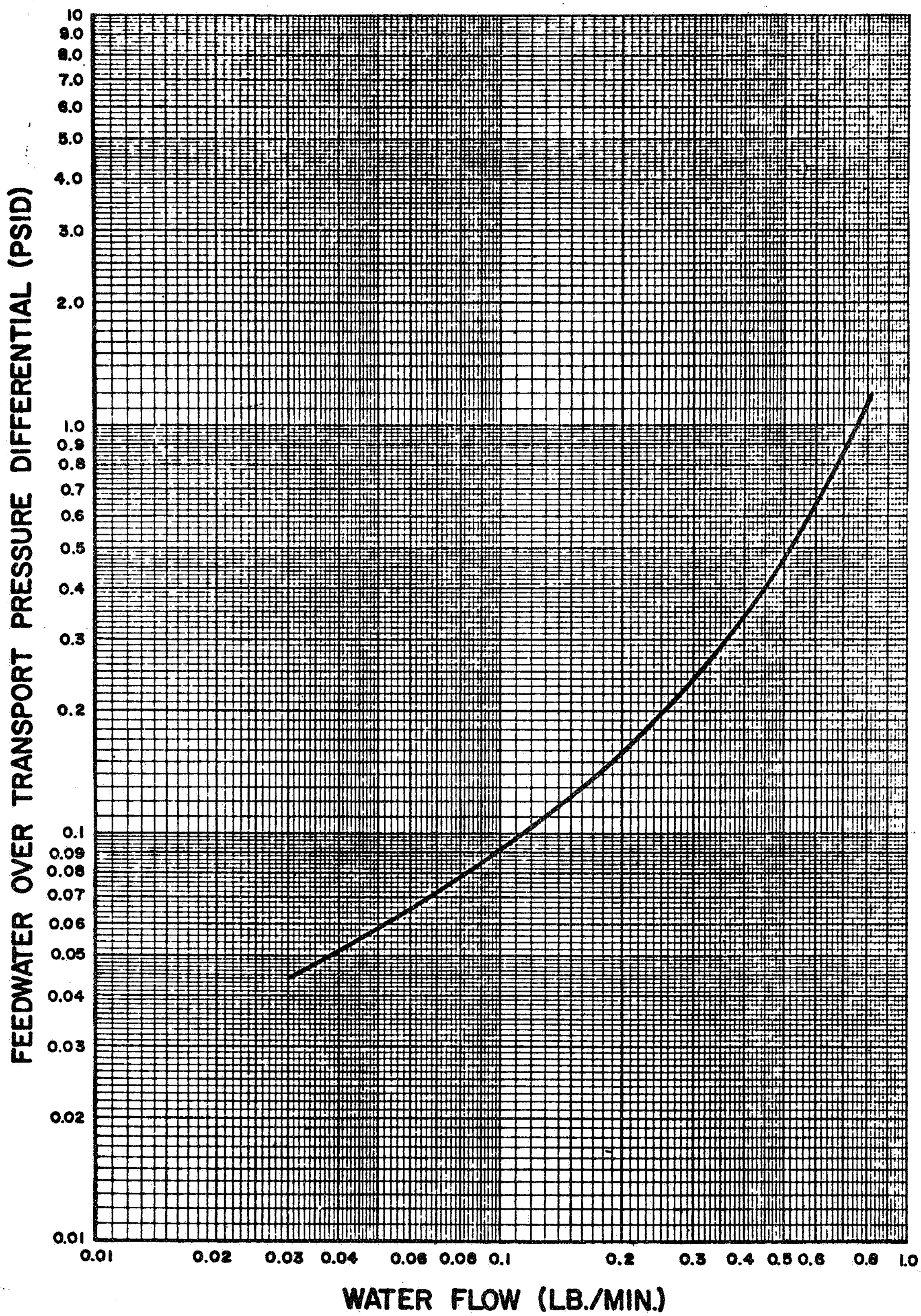

Figure 4.5-50 Check Valve Pressure Differential Versus Flow Rate

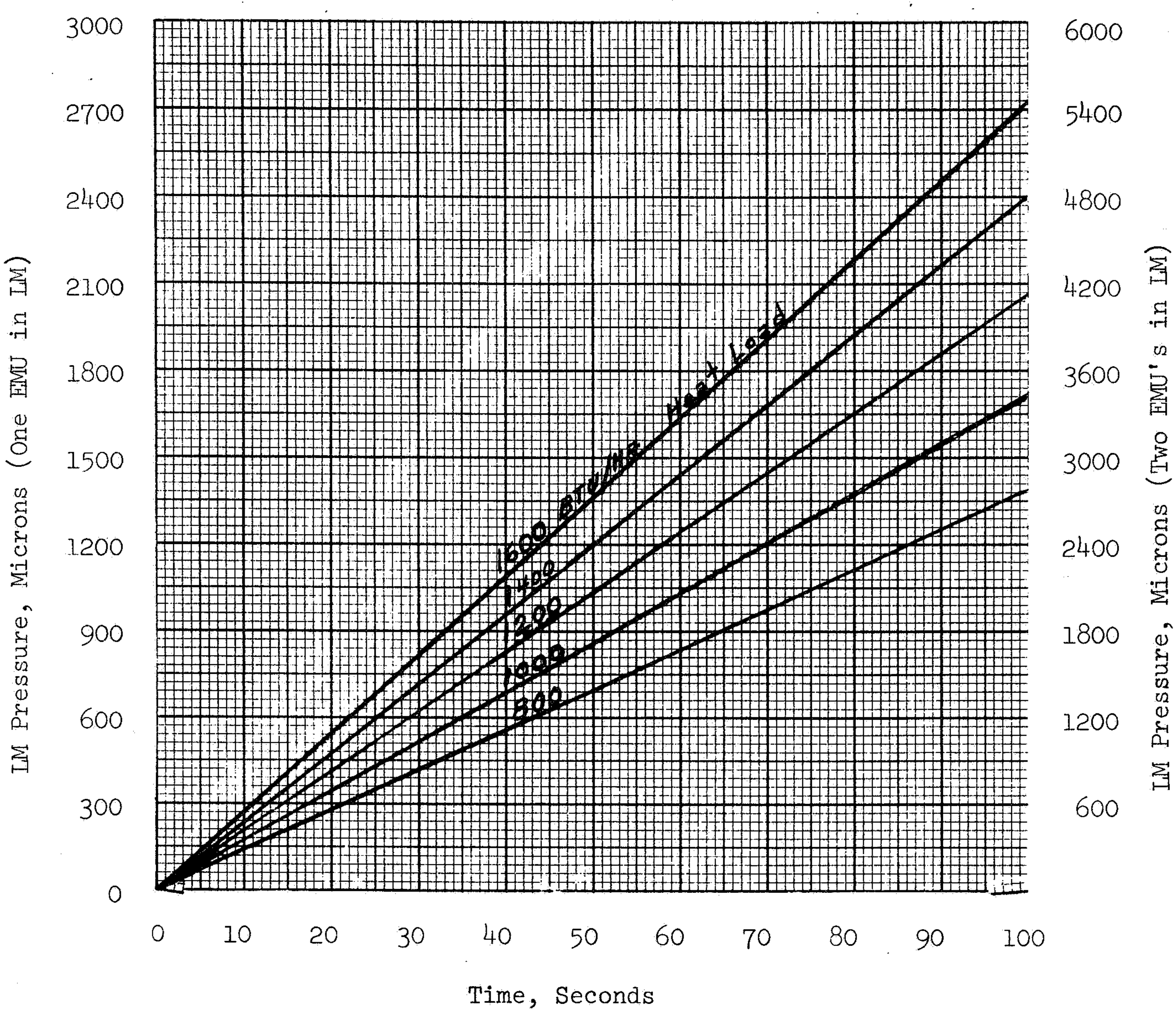

Figure 4.5-51 Rate of Increase of LM Cabin Pressure Due to EMU Sublimator Vapor

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4.5.6 Primary Oxygen Subsystem

The PLSS primary oxygen subsystem provides a supply of breathable oxygen and pressure regulation of ventilating oxygen.

4.5.6.1 Oxygen Supply

Figure 4.5-52 shows the oxygen usage rate as a function of metabolic rate and maximum allowable EMU leakage rate.

The oxygen qualtity indicator provides a visual display of the oxygen bottle pressure within the accuracy requirements of Table 4.5-11.

Figure 4.5-53 shows the effects of POS bottle prssure on suit absolute and differential pressures during LM repressurization.

Figure 4.5-53.1 shows the effect on POS bottle pressure from PGA pressurization in a 5.0 psia ambient with an initial POS pressure of 1030 psia (ground charge). Figure 4.5-53.2 shows the same effect with an initial POS pressure of 950 psia (LM recharge).

Figures 4.5-53.3 through 4.5-53.5 show the relationship between suit pressure and LM repress cabin pressure for various initial POS pressures (150, 300, and 450 psia).

The primary oxygen pressure required to maintain suit regulated pressure during LM repressurization is tabulated below for several LM repressurization times. The repressurization time is for a cabin pressure increase of .5 psia to 5.0 psia.

LM Repressurization Time Seconds	Required Primary Oxygen Pressure
100	527 psia
104	511 psia
120	422 psia
140	382 psia

The drop in POS pressure to pressurize the PGA from 5.0 psia to 8.85 psia and from 3.85 to 6.0 psia is given below for manned suit volumes of 2.0, 2.2, and 2.4 cubic feet.

Suit Volume, FT^3	Drop in POS Pressure, PSI 5.0 to 8.85 psia	Drop in POS Pressure, PSI 3.85 to 6.0 psia
2.0	34.4	19.2
2.2	37.8	20.1
2.4	41.2	23.0

Since the PLSS O_2 regulator maintains the suit pressure at 3.85 psi above ambient, the suit pressure would be greater than the LM cabin pressure after cabin repressurization has been effected. This would require a crewman to either "pop a glove" or open the purge valve prior to attempting to remove his suit. Figures 4.5-53.6 through 4.5-53.8 show the LM cabin pressure at which to shut-off the PLSS O_2 in order for a negligible pressure differential to exist at the instant the LM completes repress as a function of the PLSS O_2 supply pressure. Figures 4.5-53.9 and 4.5-53.10 show the curves and method used to derive the three working curves.

4.5.6.2 Oxygen Supply Residual

The residual oxygen for nominal depletion of the POS is .123 lbs which corresponds to a pressure of 100 psia at a temperature of 70^{o}F.

4.5.6.3 Pressure Regulation

The PLSS primary oxygen regulator characteristics are shown in Figure 4.5-54.

Figure 4.5-55 defines the bellows orifice flow rate at various ambient pressures.

Figures 4.5-56 and 4.5-56.1 illustrate the POS purge time and maximum flow rate with a failed open regulator as a function of source pressure.

Figure 4.5-56.2 illustrates the time from regulator failed closed condition until activation of the low pressure warning. This time is dependent upon metabollic rate, suit leakage, and PGA/PLSS free volume. The figure presents this time for various metabolic rates, for a suit leakage of zero, and a PGA/PLSS free volume of 2.2 cubic feet. The pressure in a PGA with maximum allowable PIA leakage will decay at 0.0114 psi/minute faster.

4.5.6.4 Initial Charge and Pressure Decay Prior to Use

The ground charging characteristics of the PLSS primary oxygen supply are shown in Figure 4.5-57.
Pressure decay characteristics of the POS between charging and use are given by Figure 4.5-57.1.

4.5.6.5 Recharge

The recharge characteristics of the PLSS primary oxygen supply are shown in Figure 4.5-58.

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The ground charging characteristics of the PLSS primary oxygen supply are shown in Figure 4.5-57.
Pressure decay characteristics of the POS between charging and use are given by Figure 4.5-57.1.

4.5.6.5 Recharge

The recharge characteristics of the PLSS primary oxygen supply are shown in Figure 4.5-58.

4.5.6.6 Pressure/Mass Relationship

The PLSS oxygen quantity (mass) as a function of the POS source pressure is shown in Figure 4.5-59. Steady state temperature values were assumed in preparing the family of curves.

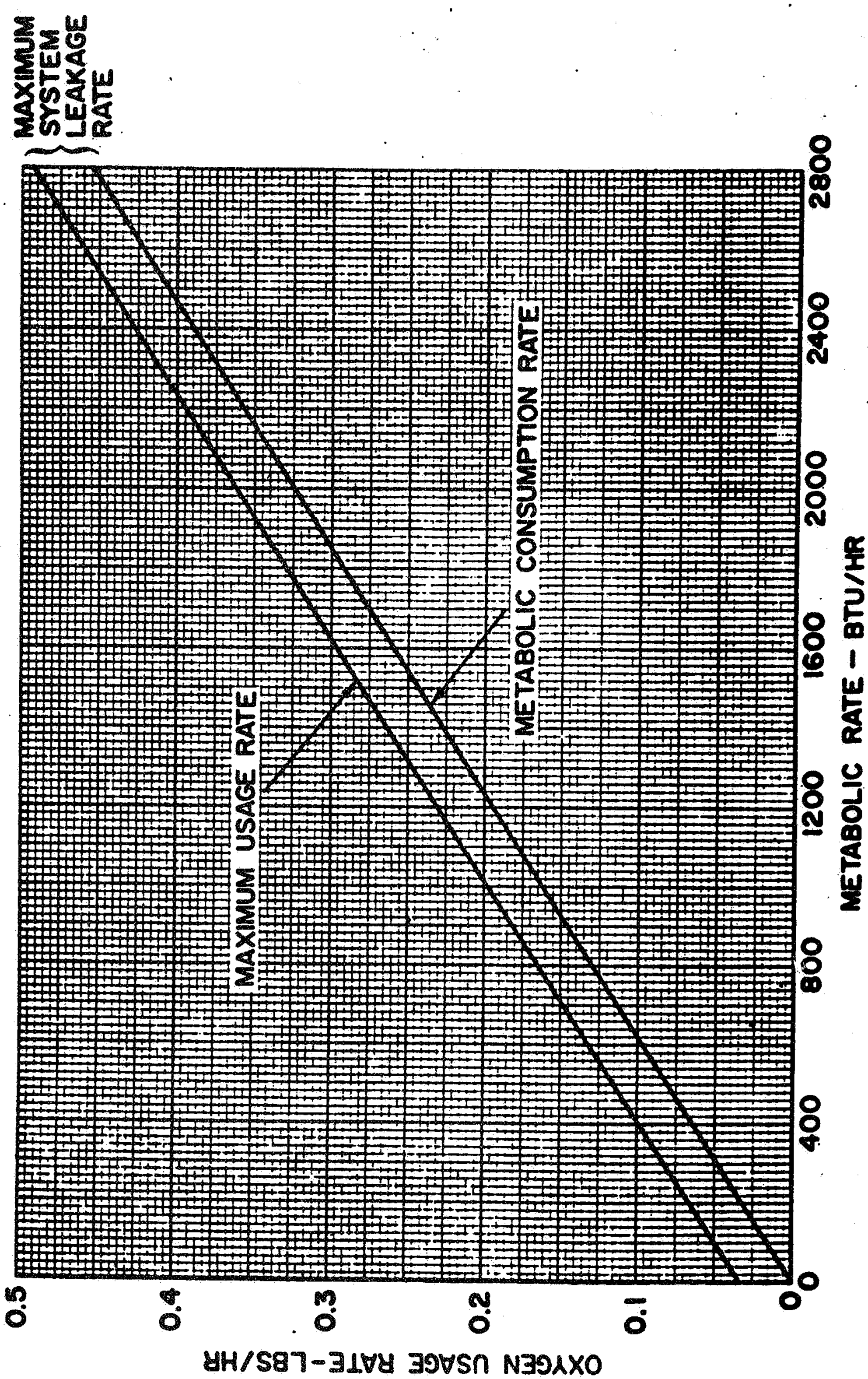
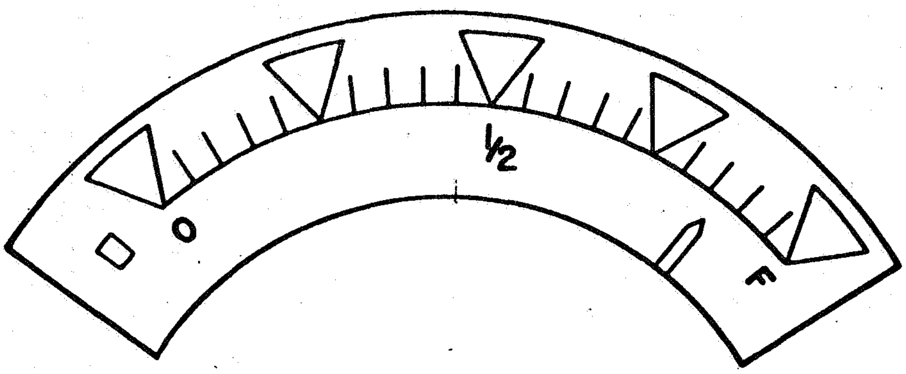


Figure 4.5-52 Oxygen Usage Rate Versus Metabolic Rate

BACK

Table 4.5-11 Oxygen Quantity Indicator Markings and Accuracies



MARKING	OXYGEN BOTTLE PRESSURE RANGE: HORIZONTAL POSITION AND ZERO G	OXYGEN BOTTLE PRESSURE RANGE: ALL OTHER POSITIONS
0	160 psia Maximum 110 psia Nominal 60 psia Minimum	187 psia Maximum 110 psia Nominal 33 psia Minimum
1/4	410 psia Maximum 360 psia Nominal 310 psia Minimum	437 psia Maximum 360 psia Nominal 283 psia Minimum
1/2	660 psia Maximum 610 psia Nominal 560 psia Minimum	687 psia Maximum 610 psia Nominal 533 psia Minimum
3/4	910 psia Maximum 860 psia Nominal 810 psia Minimum	937 psia Maximum 860 psia Nominal 783 psia Minimum
F	1160 psia Maximum 1110 psia Nominal 1060 psia Minimum	1187 psia Maximum 1110 psia Nominal 1033 psia Minimum

Each increment of indicator represents 50 psia.

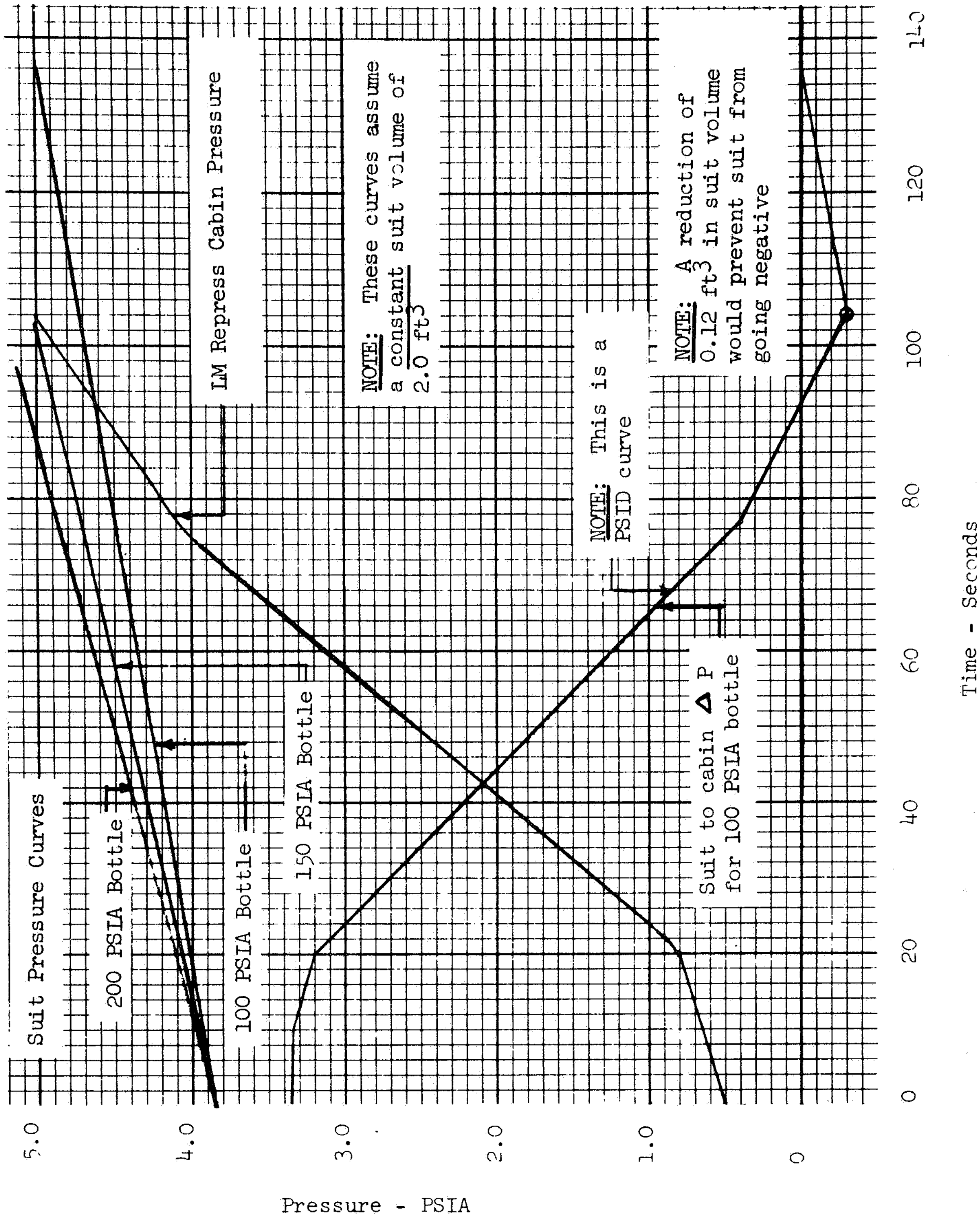


Figure 4.5-53 LM Repress Cabin Pressure Vs. Suit Pressure on PLSS

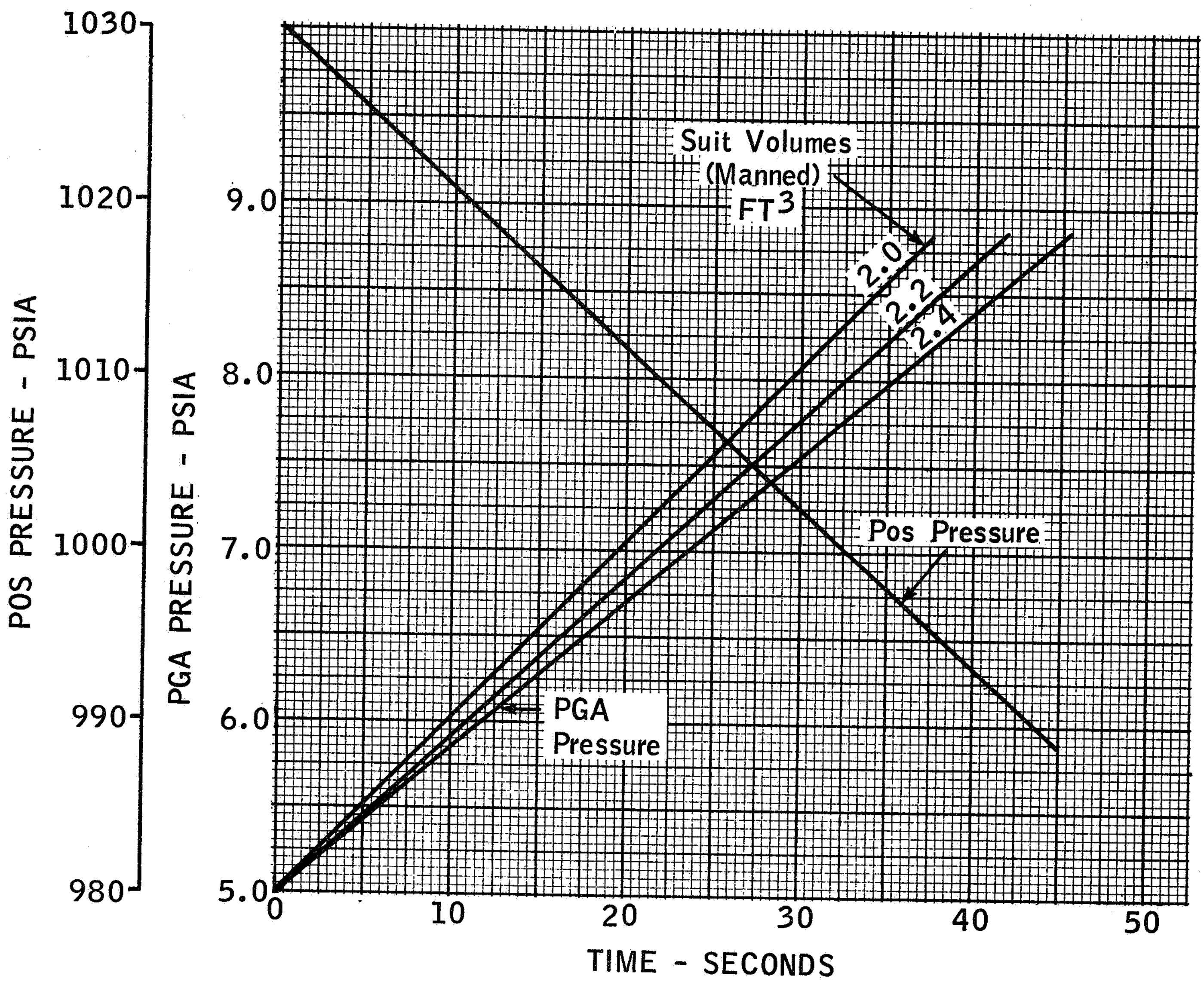


Figure 4.5-53.1 POS and PGA Pressure versus Time for PGA Pressurization Initial POS Pressure - 1030 psia

5.0 psia Ambient

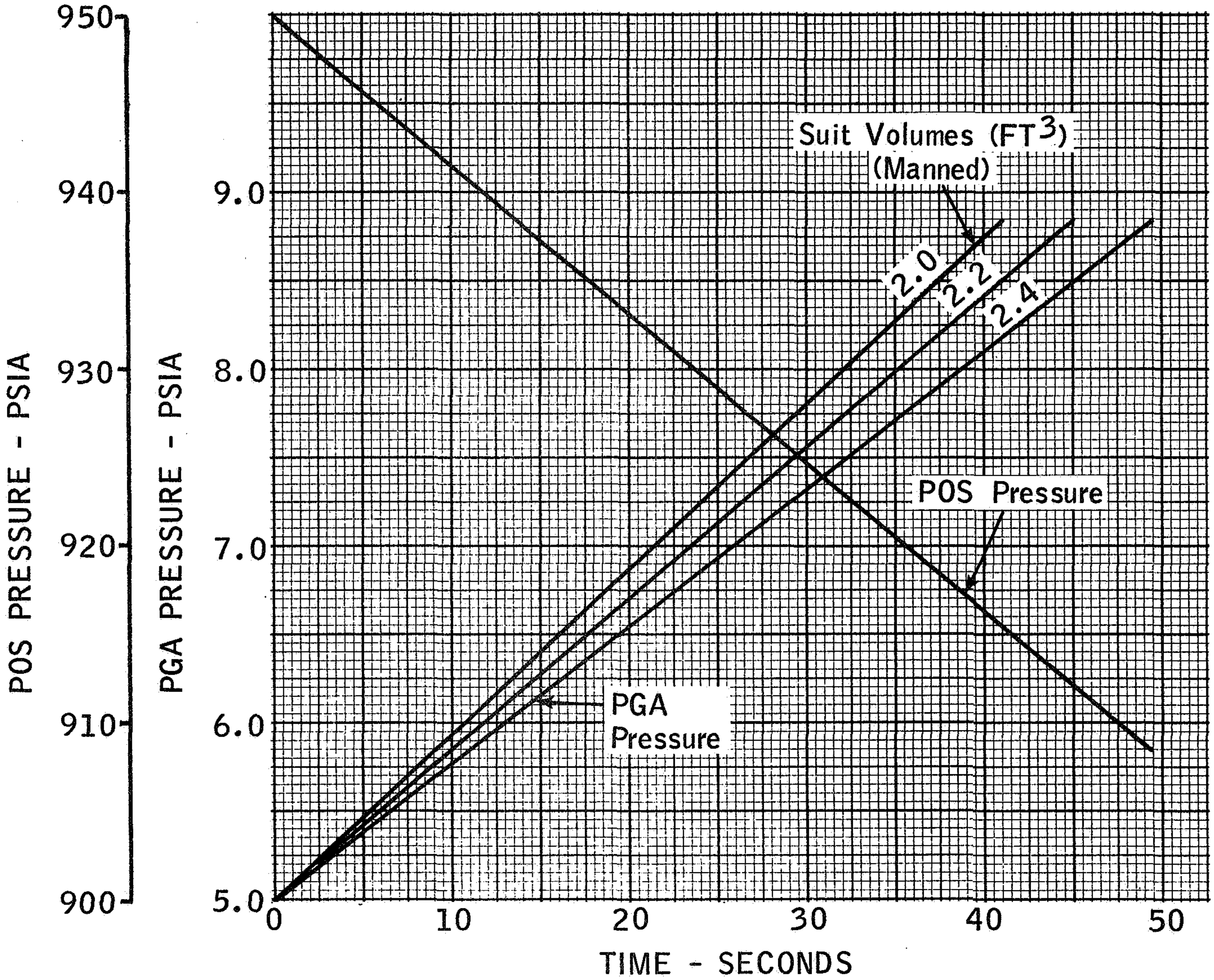


Figure 4.5-53.2 POS and PGA Pressure versus Time for PGA Pressurization
Initial POS Pressure - 950 psia

5.0 psia Ambient

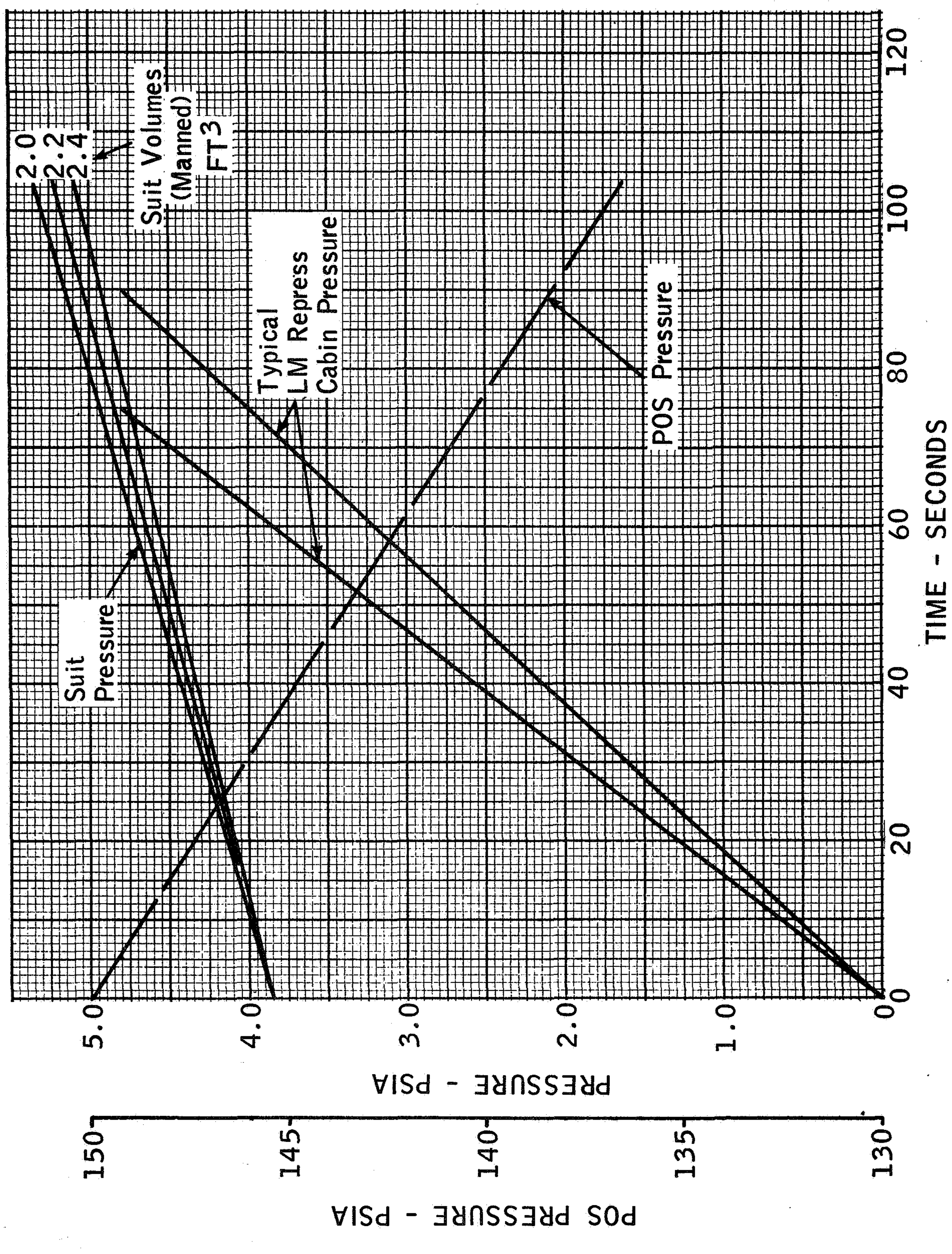


Figure 4.5-53.3 Suit Pressure versus Time for LM Repress On PLSS - Initial POS Pressure - 150 psia

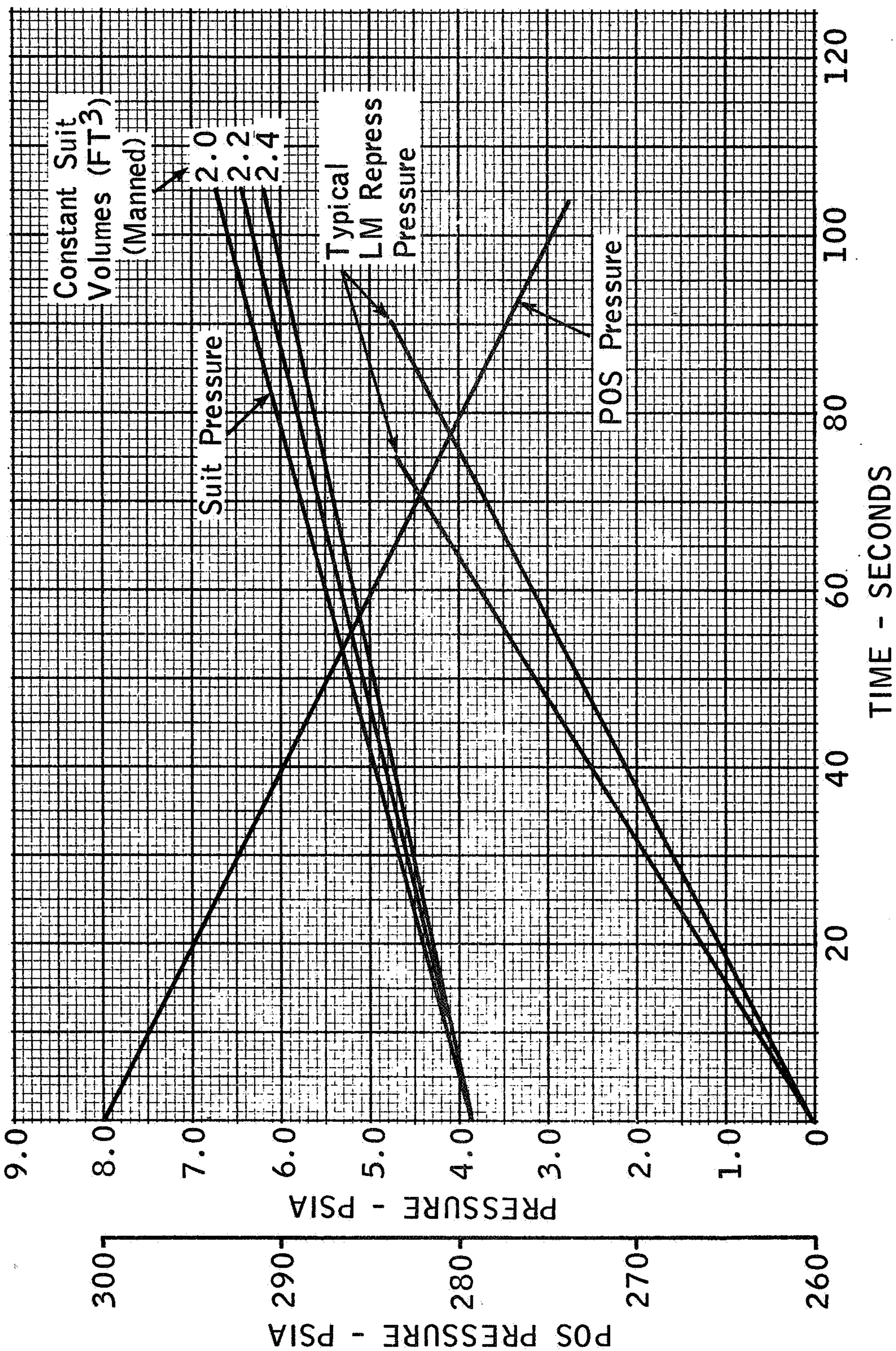


Figure 4.5-53.4 Suit Pressure versus Time for LM Repress - On PLSS
Initial POS Pressure - 300 psia

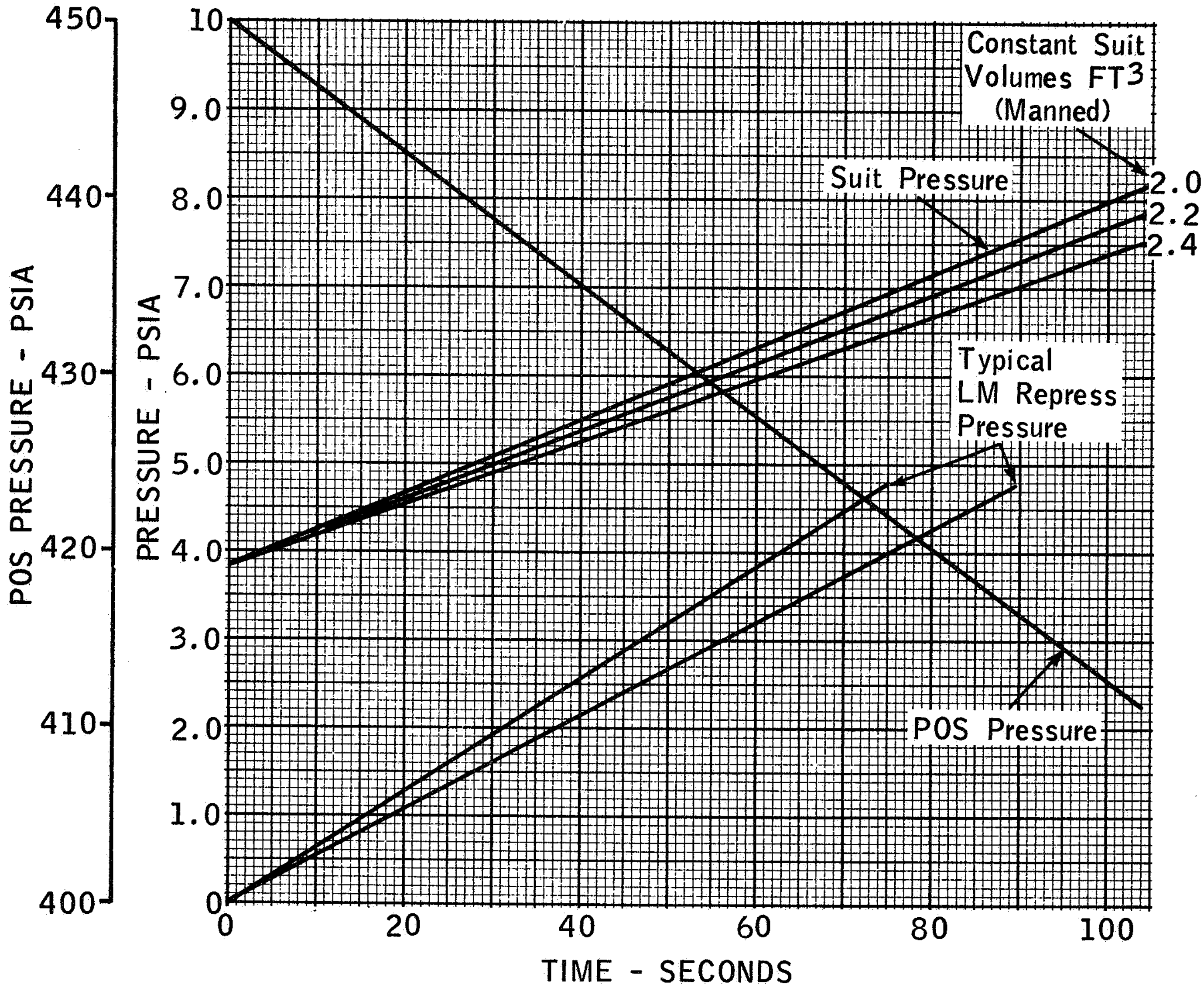


Figure 4.5-53.5 Suit Pressure versus Time for LM Repress - On PLSS
Initial POS Pressure - 450 psia

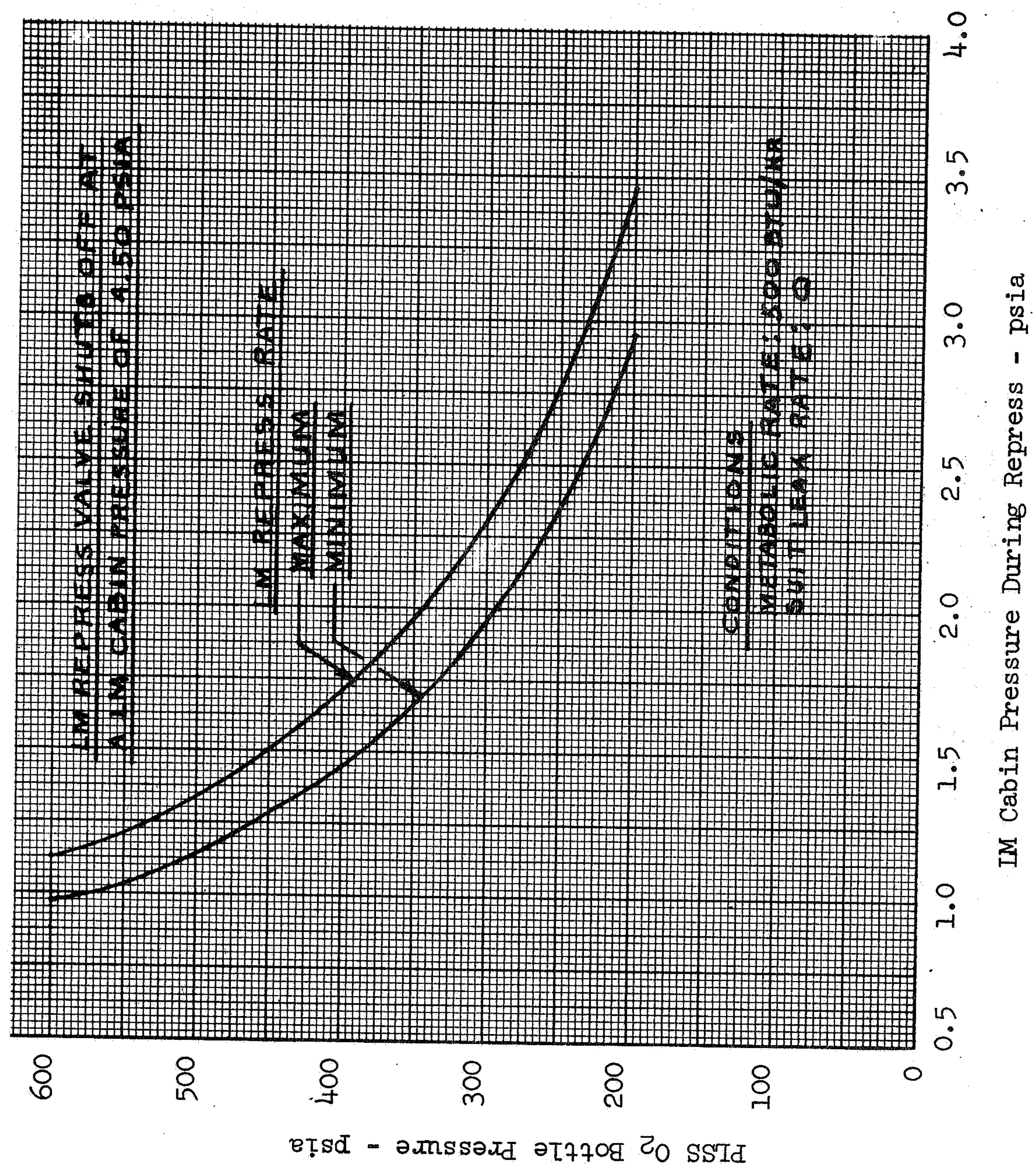


Figure 4.5-53.6 IM Cabin Pressure at which to Terminate PLSS O_2 During IM Cabin Repress (Final IM Pressure = 4.50 psia)

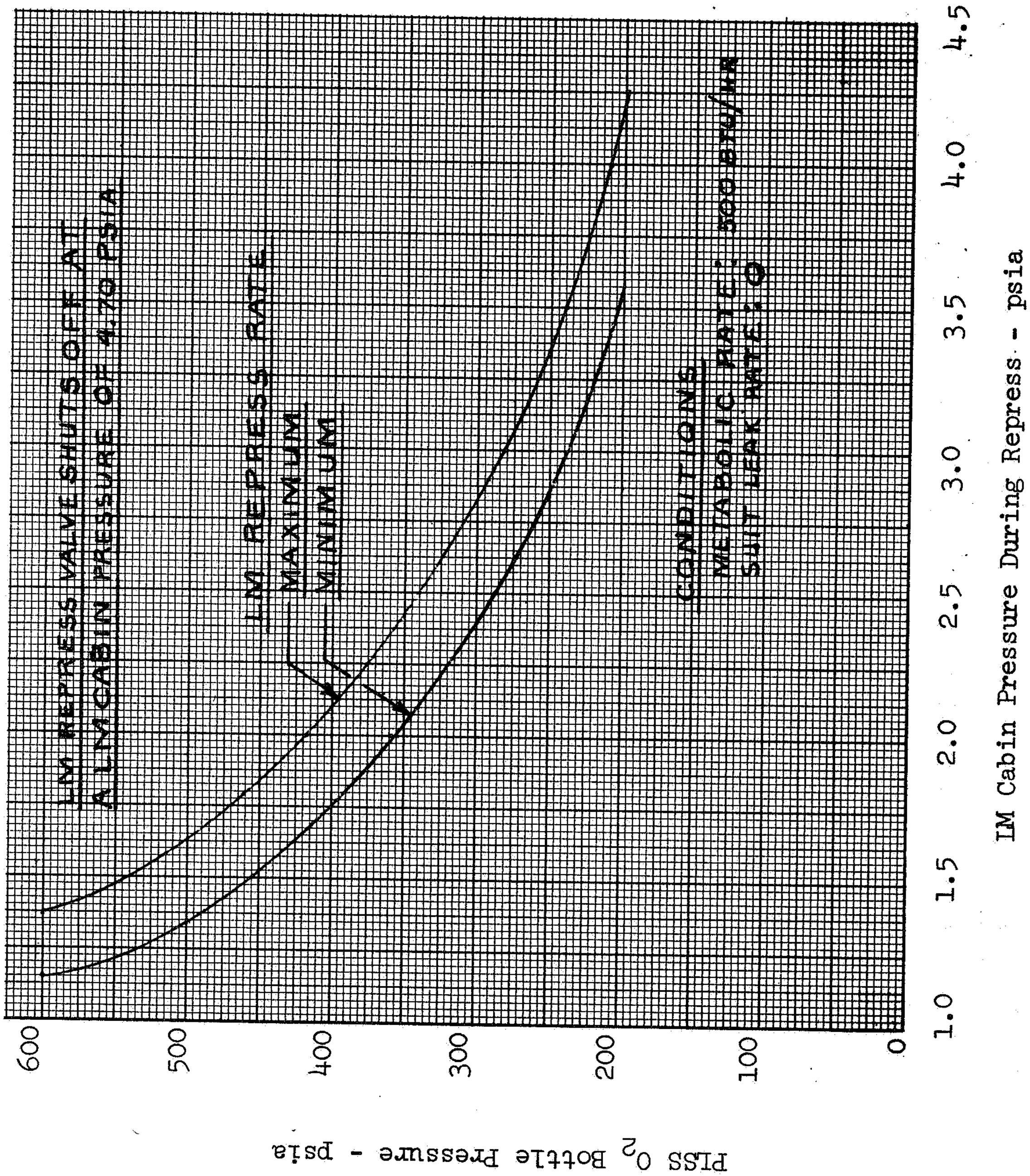


Figure 4.5-53.7 LM Cabin Pressure at which to Terminate PLSS O_2 During LM Cabin Repress (Final LM Pressure = 4.70 psia)

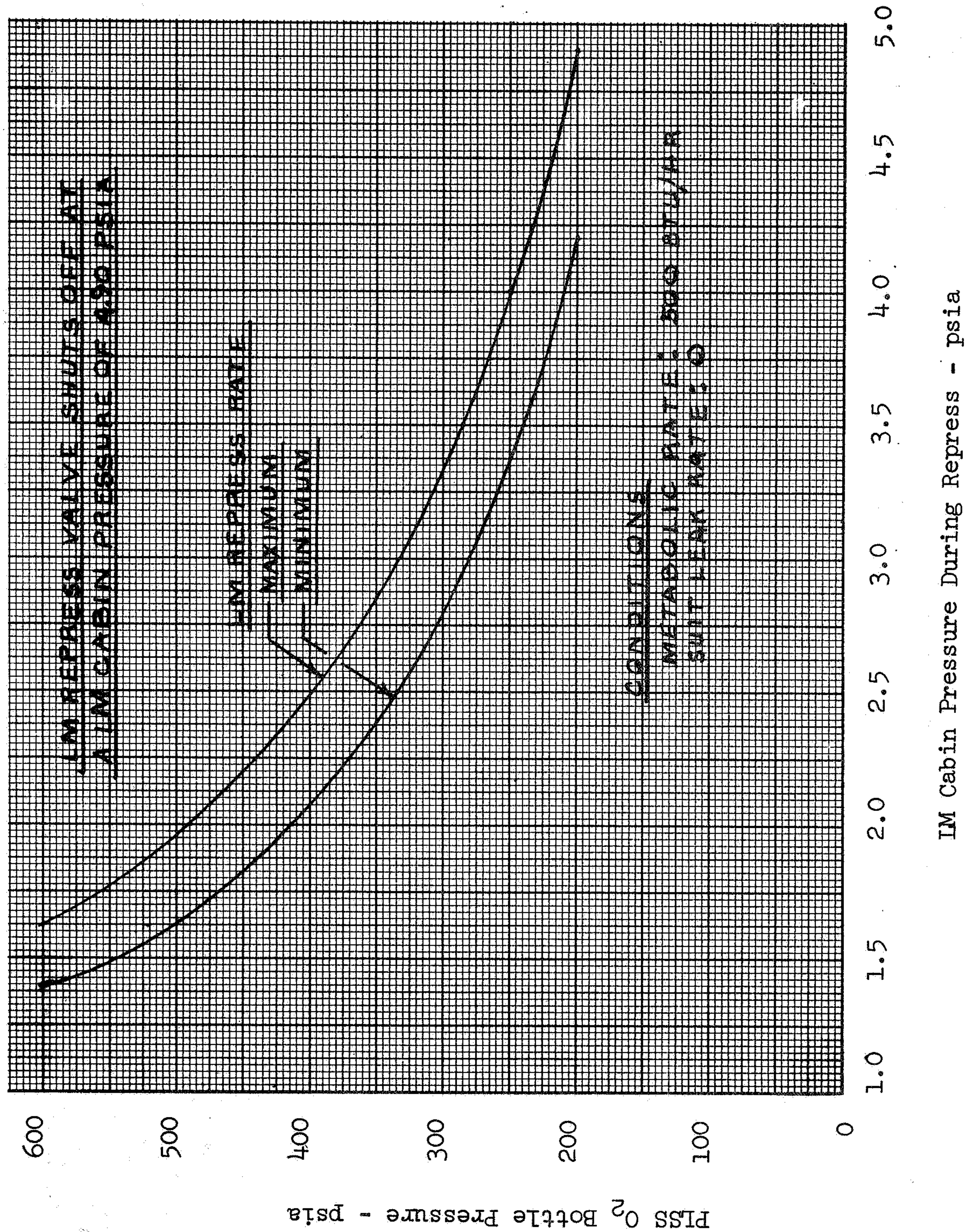


Figure 4.5-53.8 LM Cabin Pressure at which to Terminate PLSS O_2 During LM Cabin Repress (Final LM Pressure = 4.90 psia)

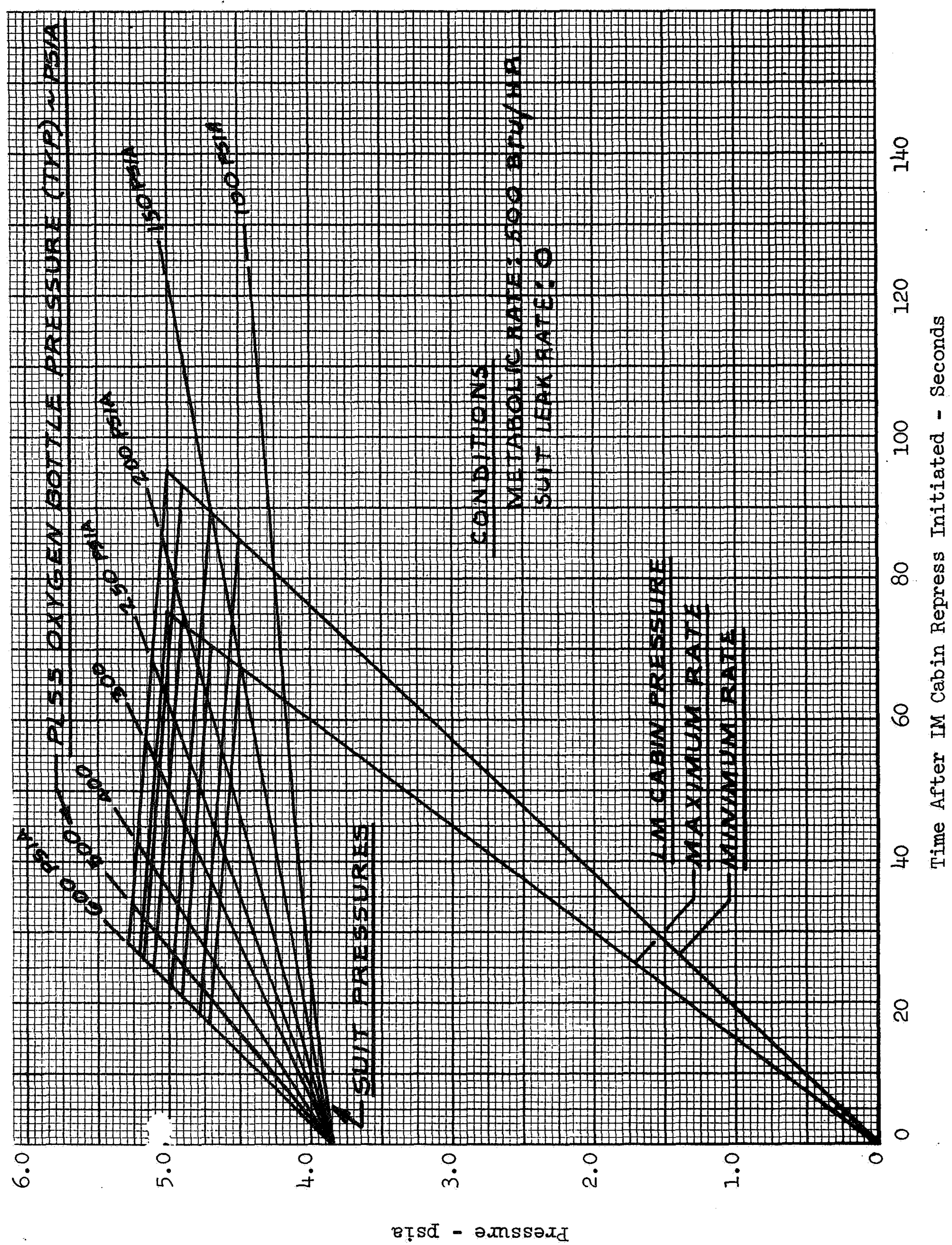


Figure 4.5-53.9 LM Cabin Pressure and Suit Pressure (With Breathe Down Effects Indicated) Versus Time

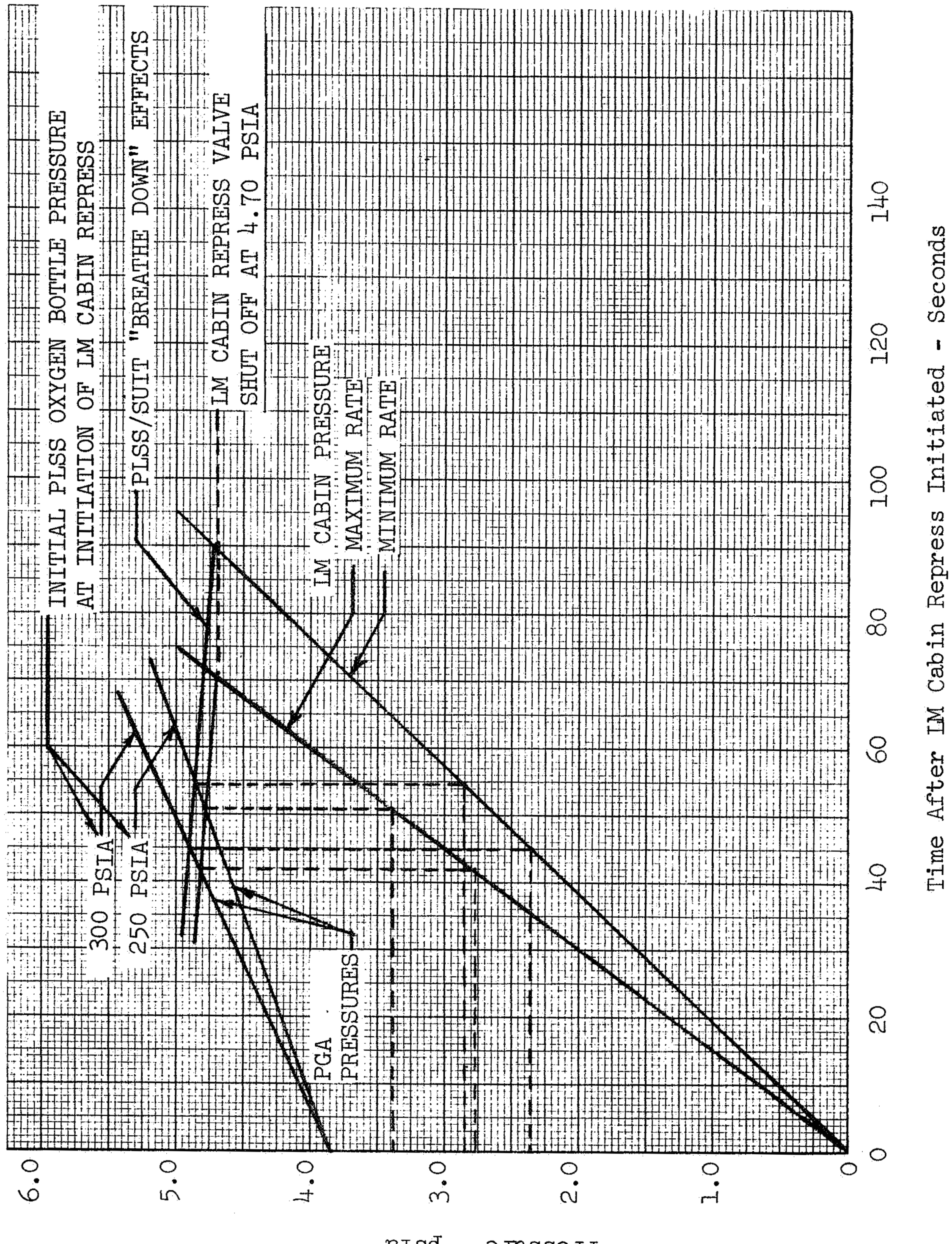


Figure 4.5-53.10 Demonstration of Method Used to Derive Working Curves (Figures 4.5-53.6 through 4.5-53.8) From Figure 4.5-53.9

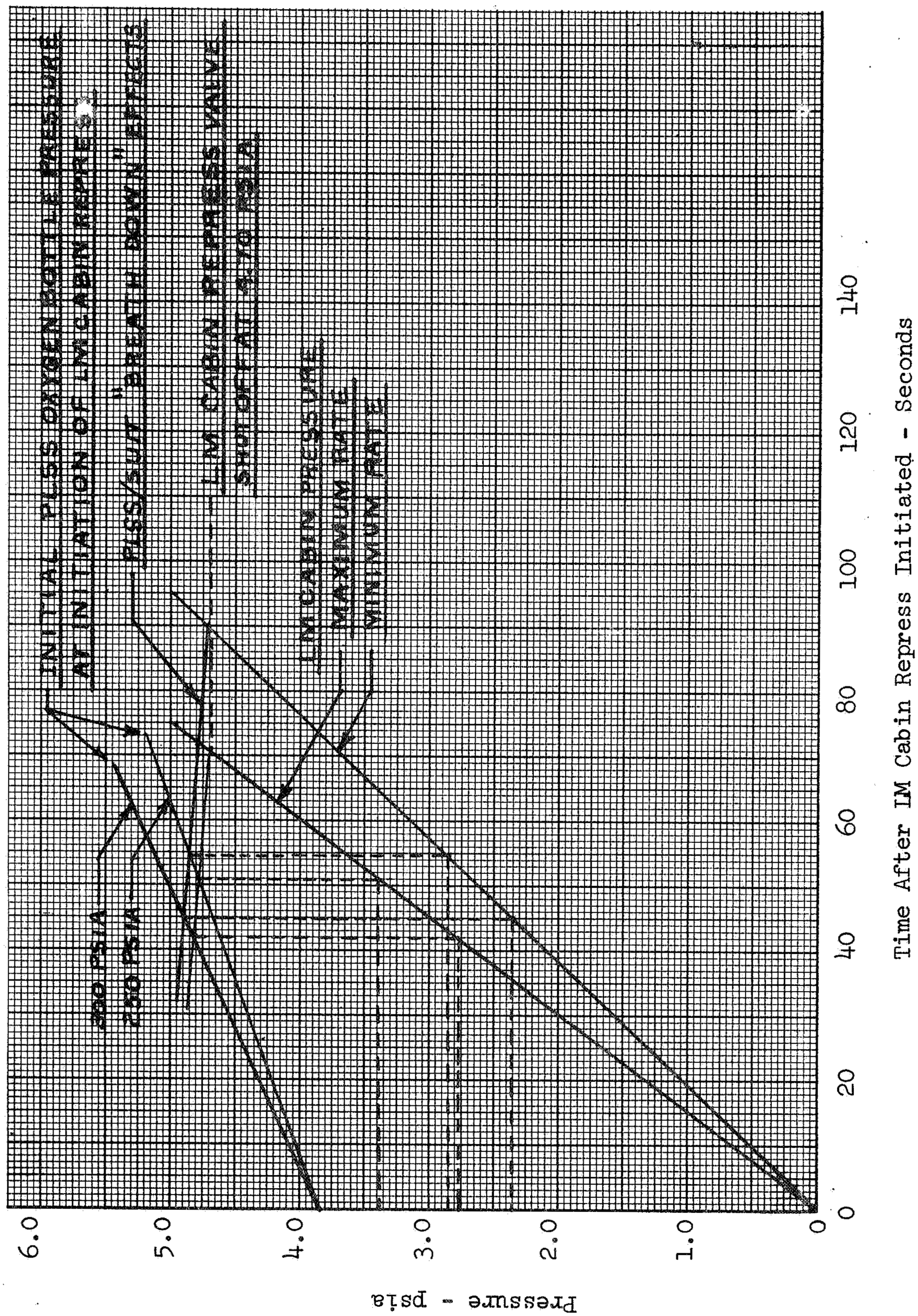


Figure 4.5-53.10 Demonstration of Method Used to Derive Working Curves (Figures 4.5-53.b through 4.5-53.8) From Figure 4.5-53.9

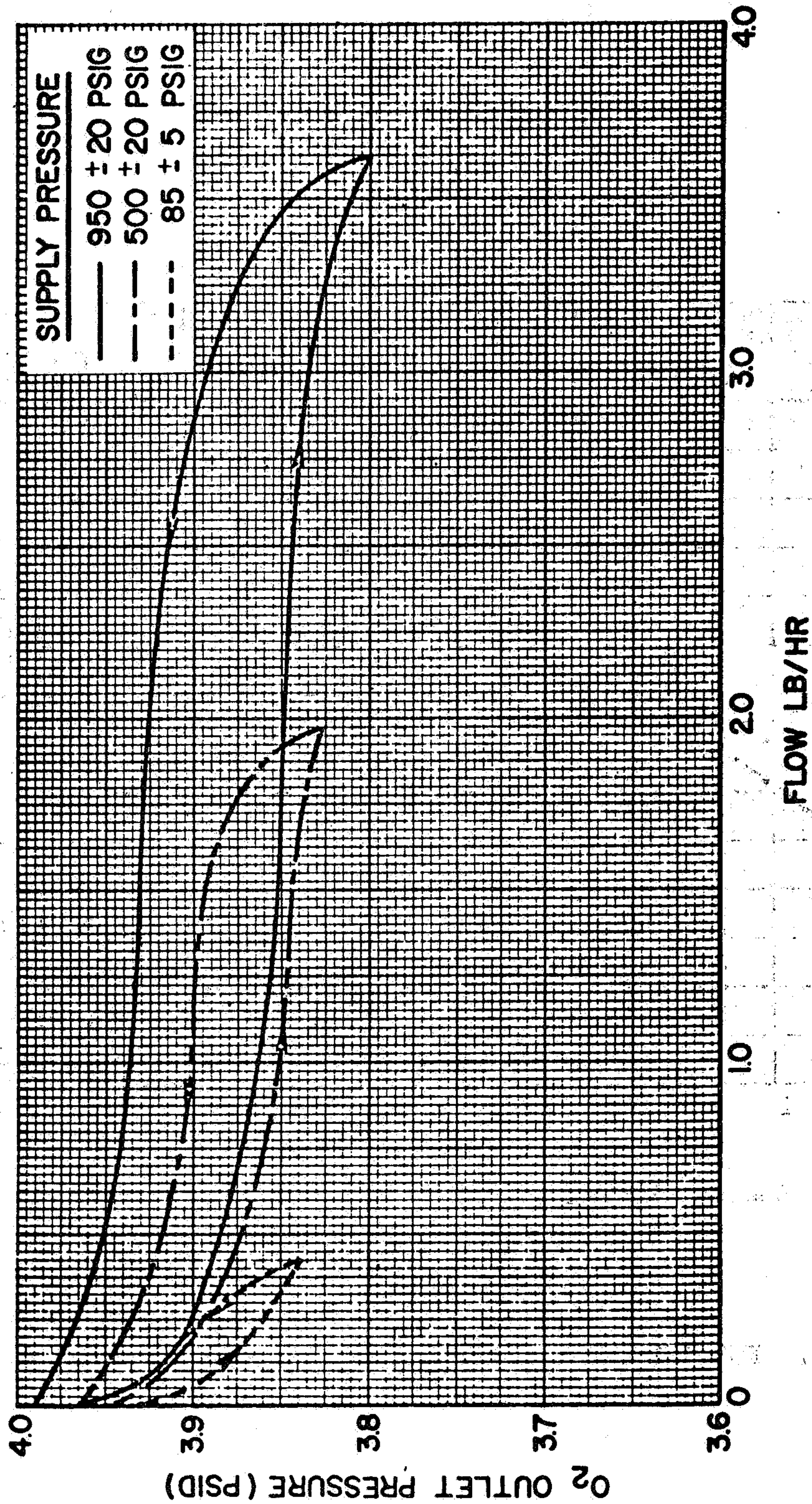


Figure 4.5-54 Primary O_2 Regulator Performance

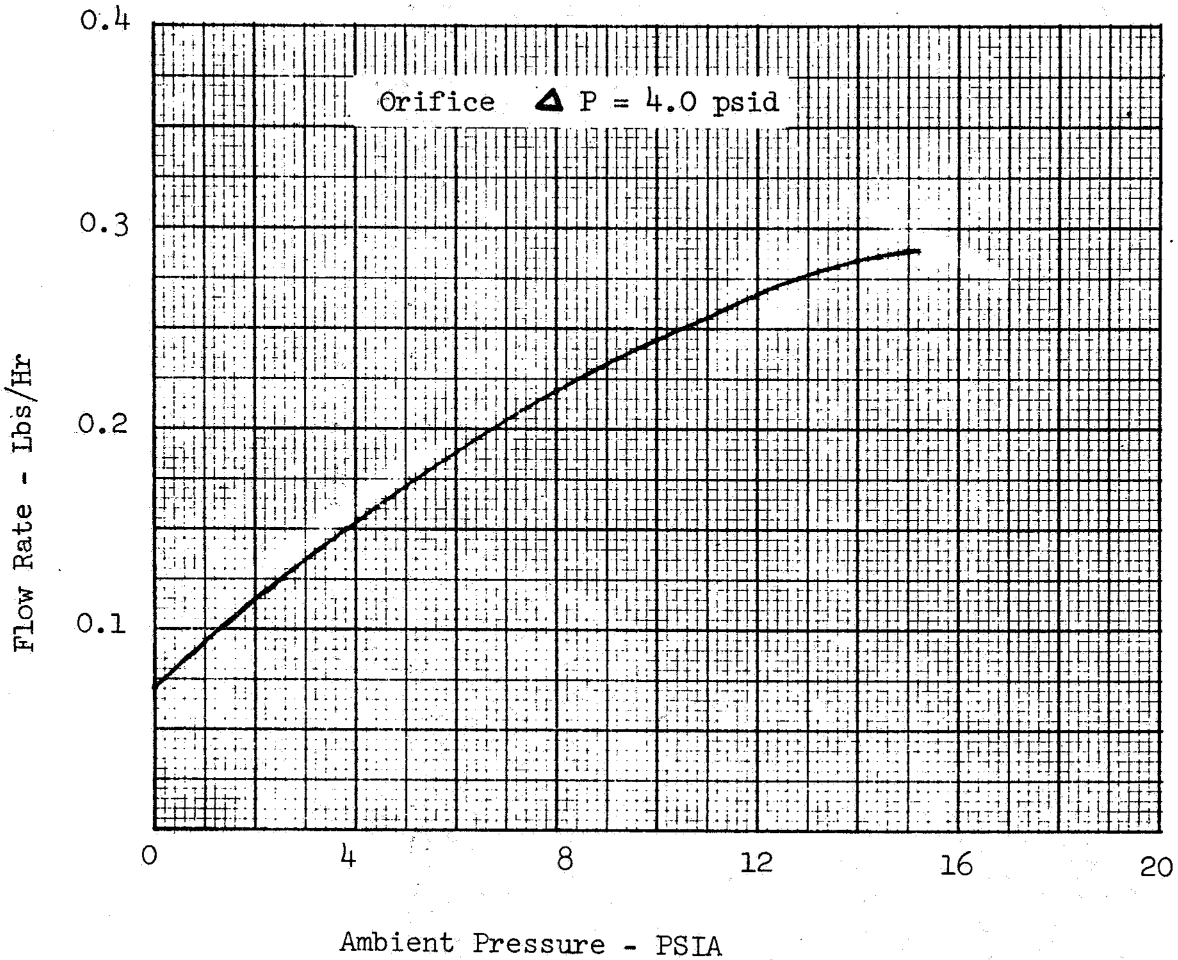


Figure 4.5-55 POS Bellows Orifice Characteristic

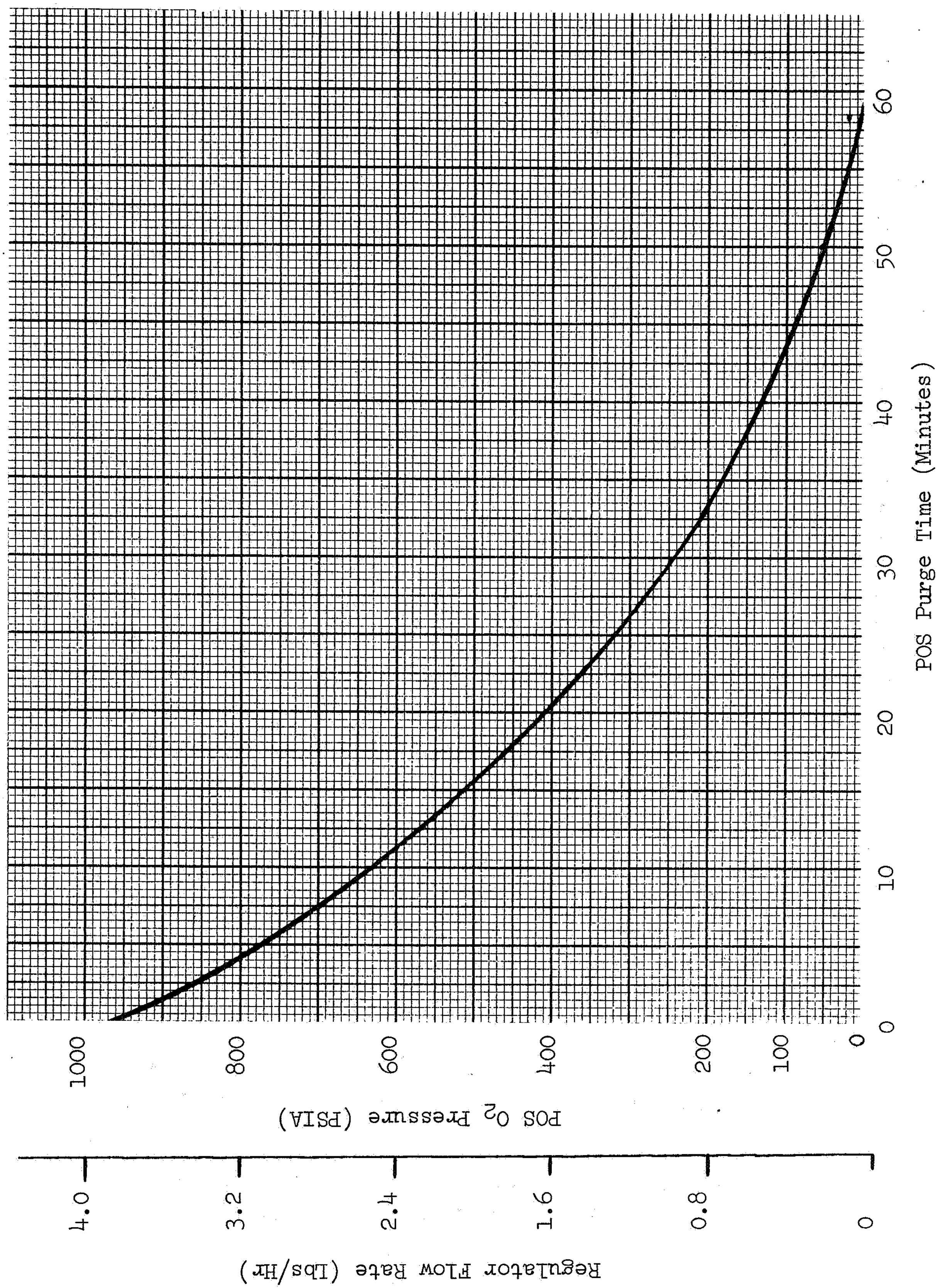


Figure 4.5-56 POS Purge Time with Failed Open Regulator

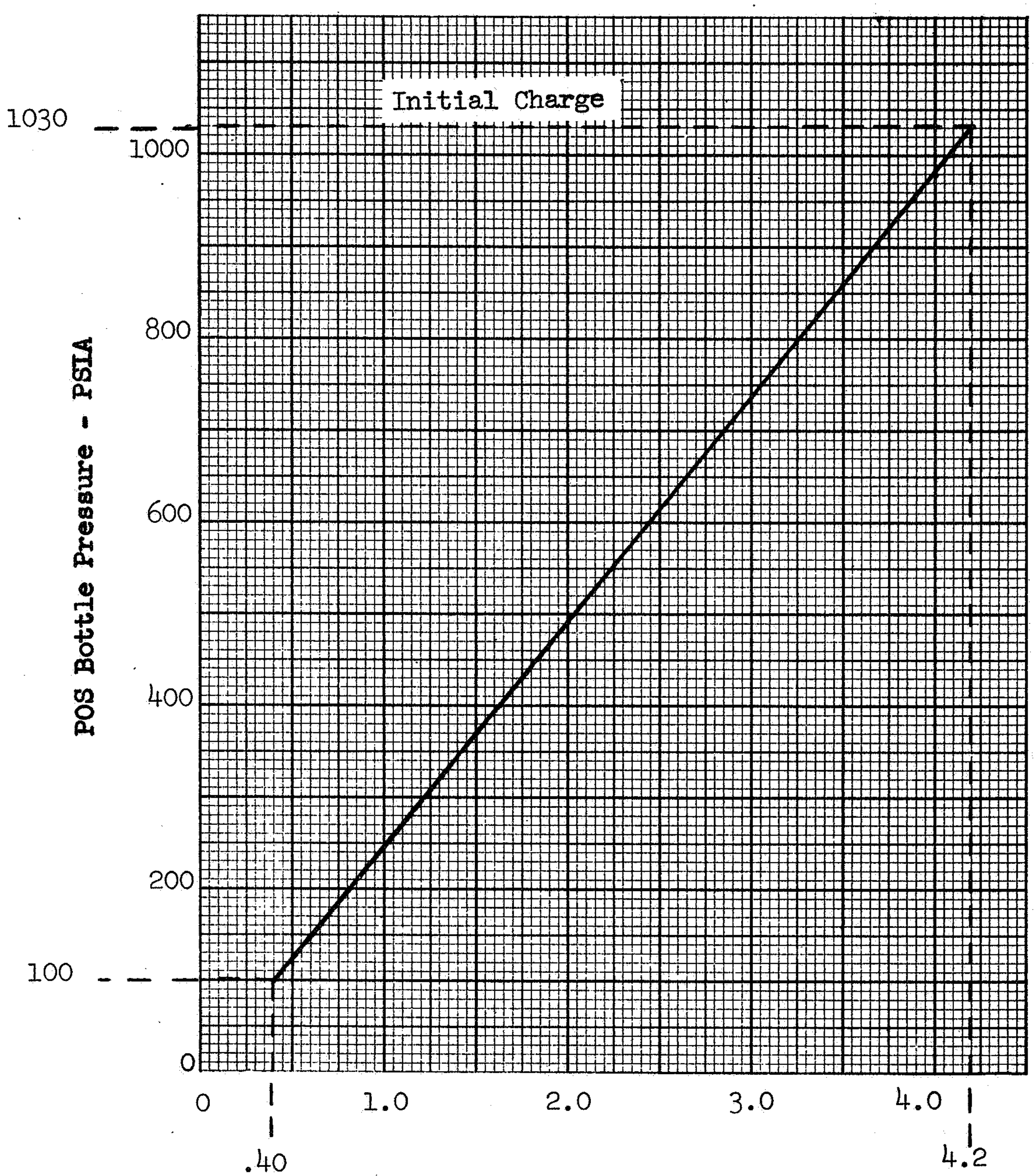


Figure 4.5-56.1 O_2 Bottle Pressure Vs. Maximum Regulator Flow in Failed Open Position

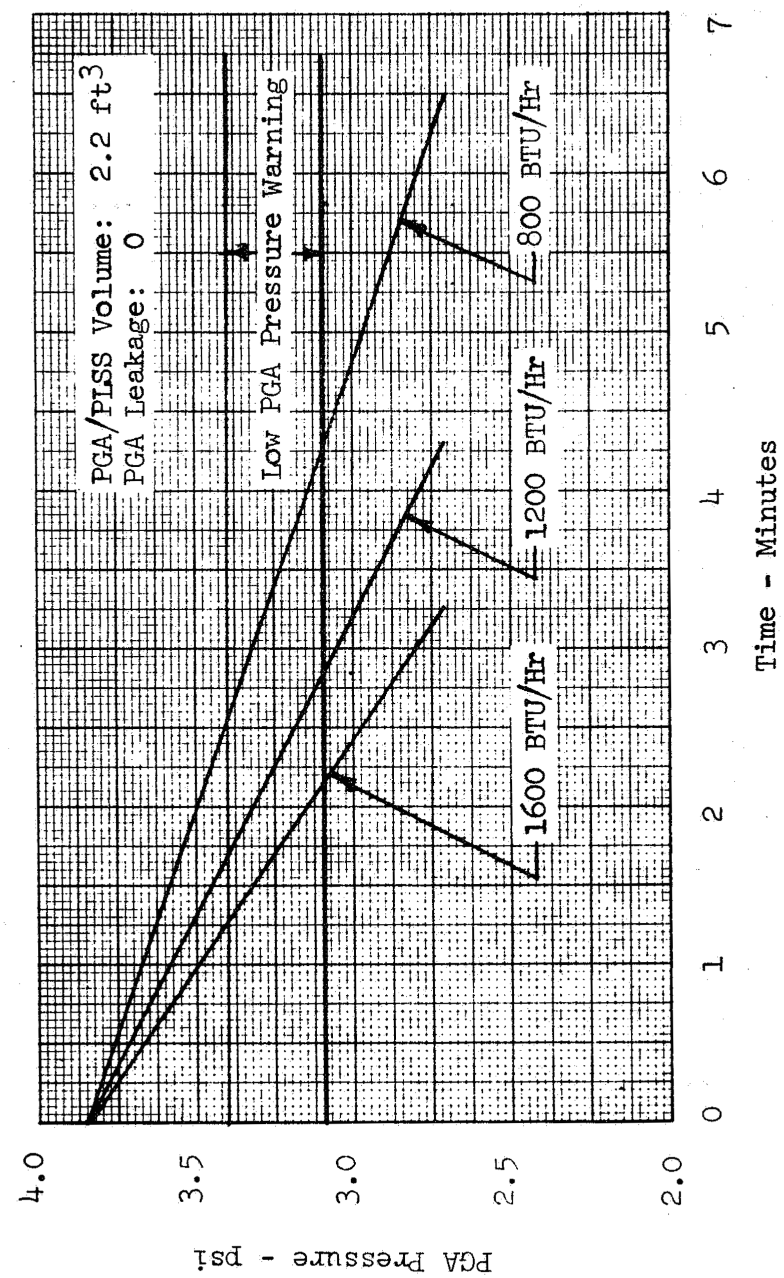


Figure 4.5-56.2 Time Prior to Low Pressure Warning With Failed Closed POS Regulator

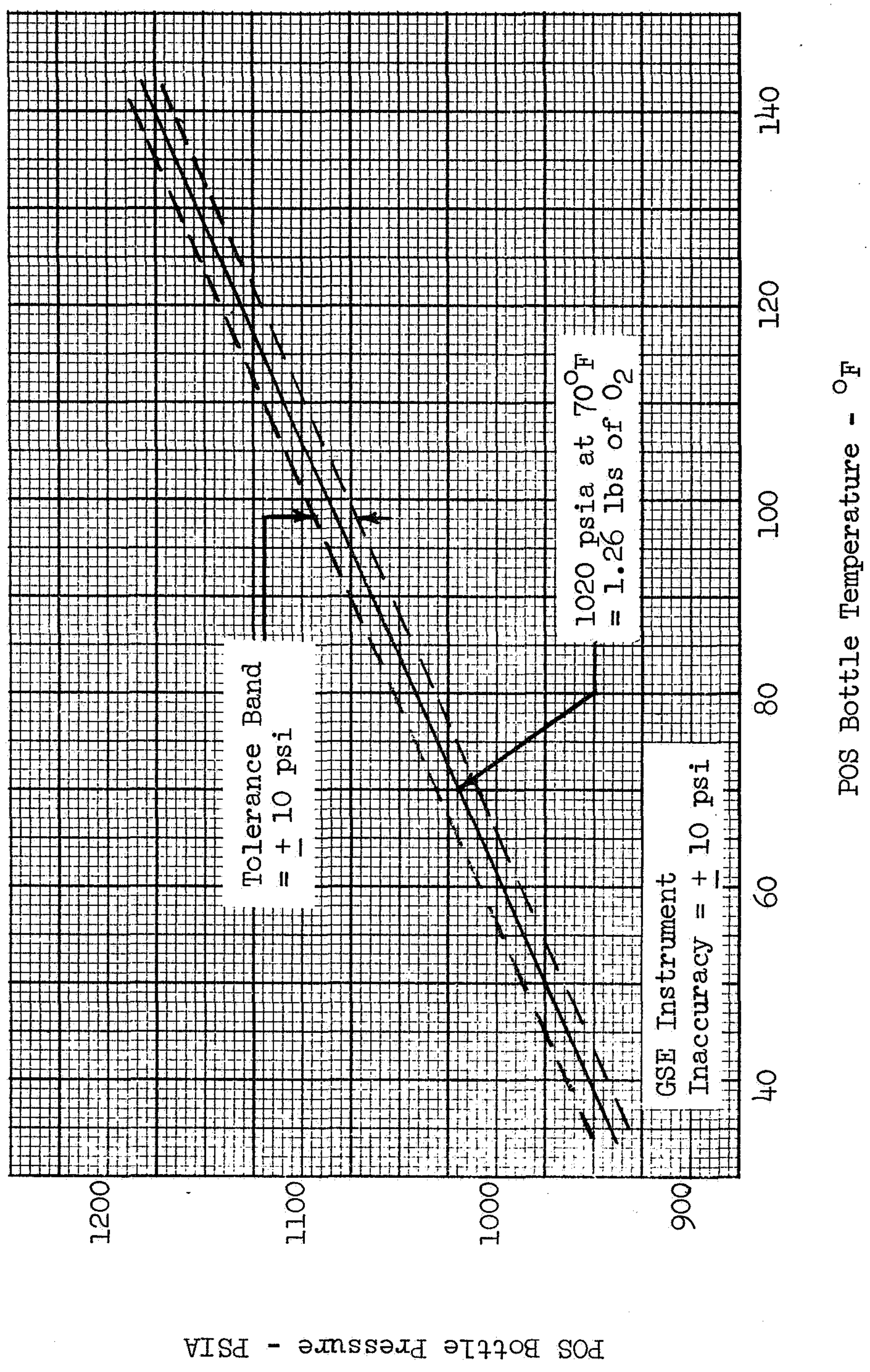


Figure 4.5-57 POS Bottle Temperature Vs. Pressure - Ground Charging

NOTE: PLSS POS Leakage

1. Spec. Max. = 0.424 psia/Hr.
2. Nominal = 0.212 psia/Hr.

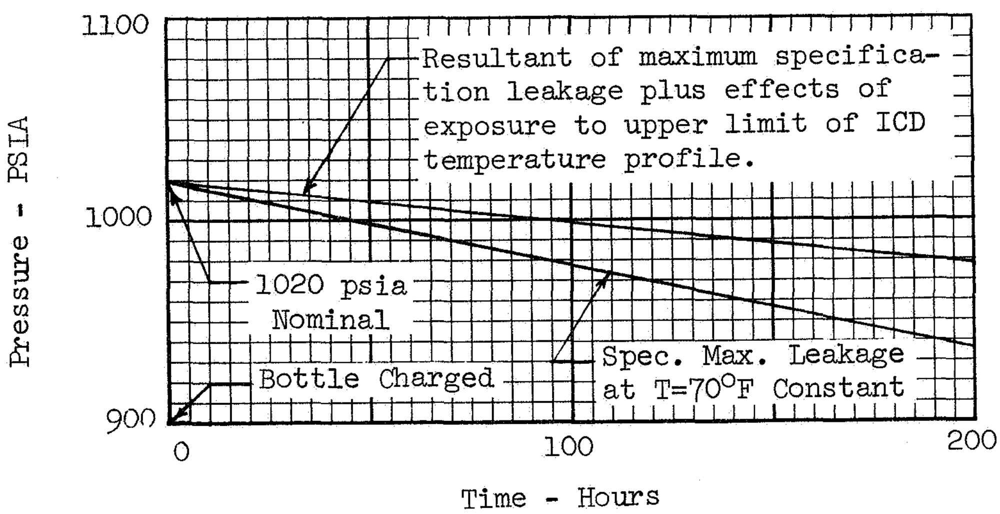


Figure 4.5-57.1 PLSS POS Bottle Pressure Vs. Stowage Time

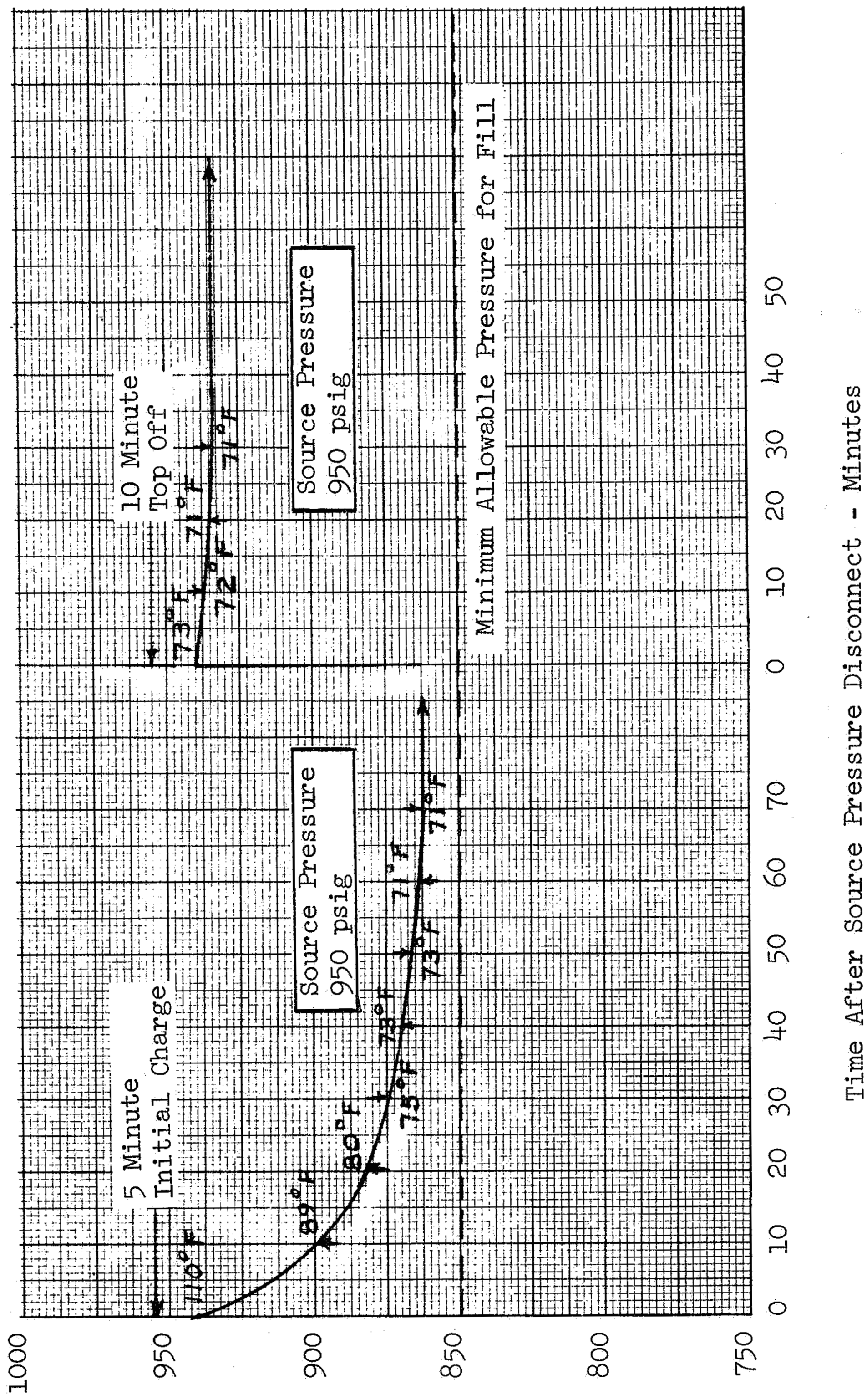


Figure 4.5-58C POS Charge Curves (Cont'd)

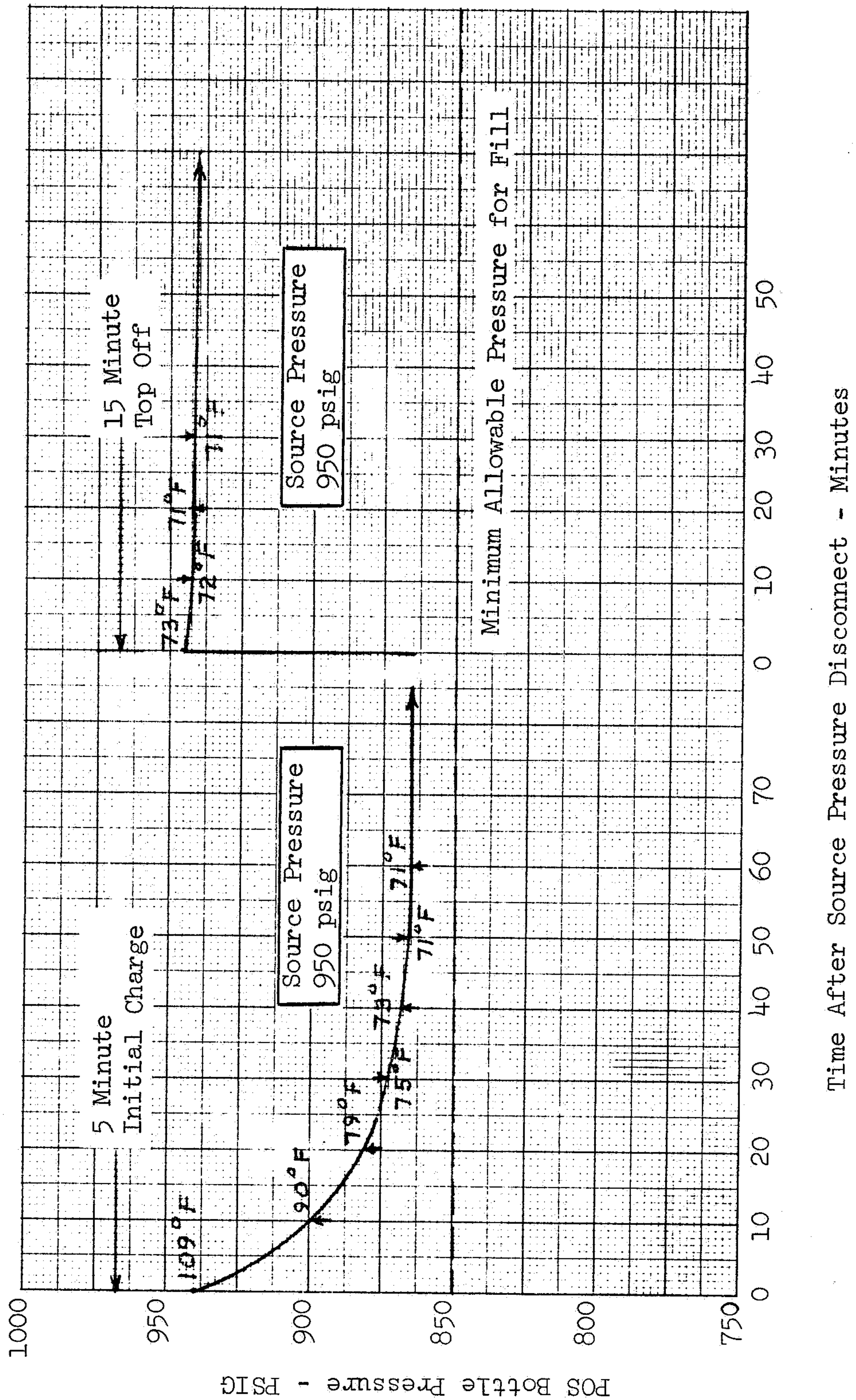


Figure 4.5-58D POS Charge Curves (Cont'd)

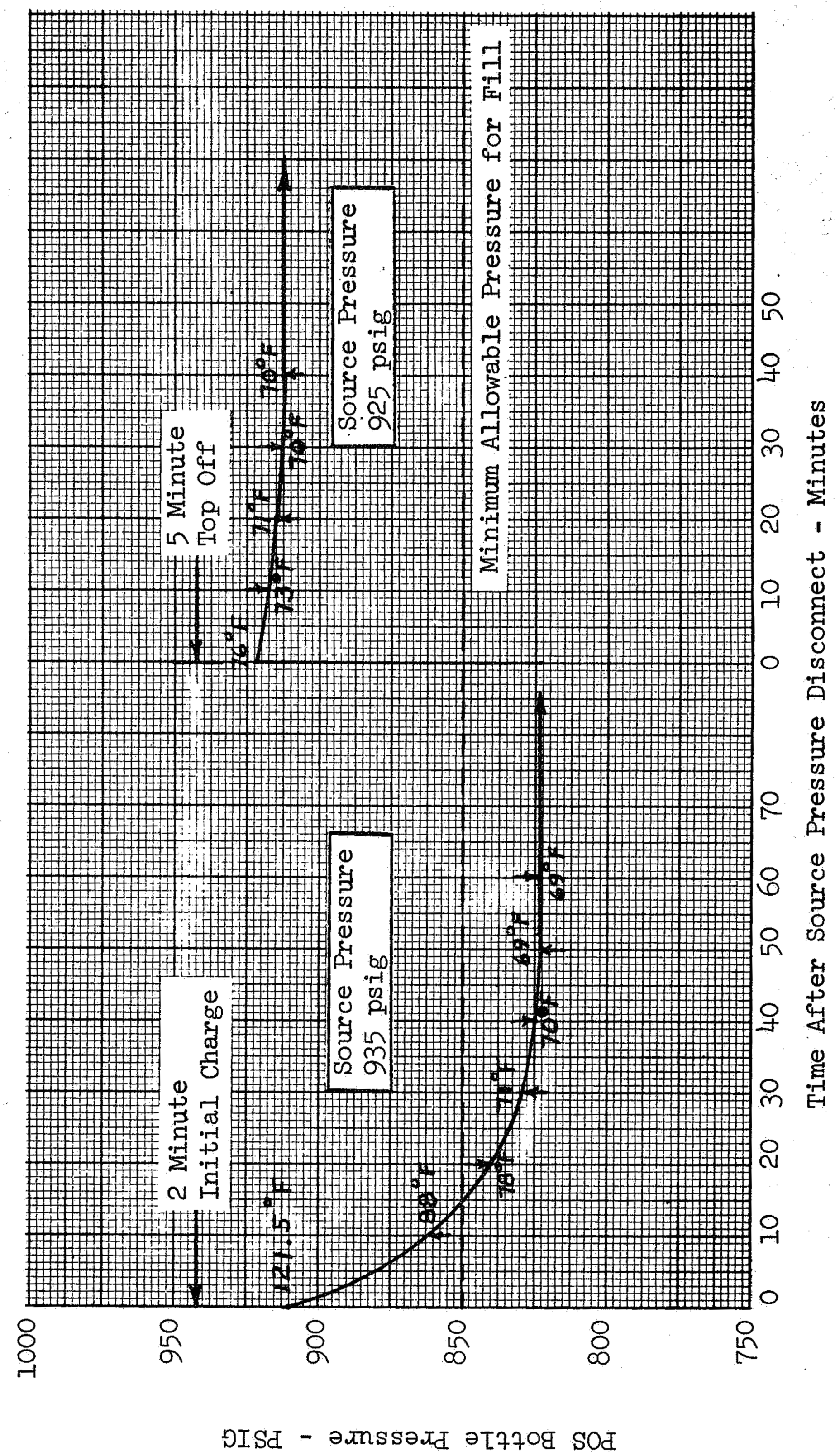


Figure 4.5-58E POS Charge Curves (Cont'd)

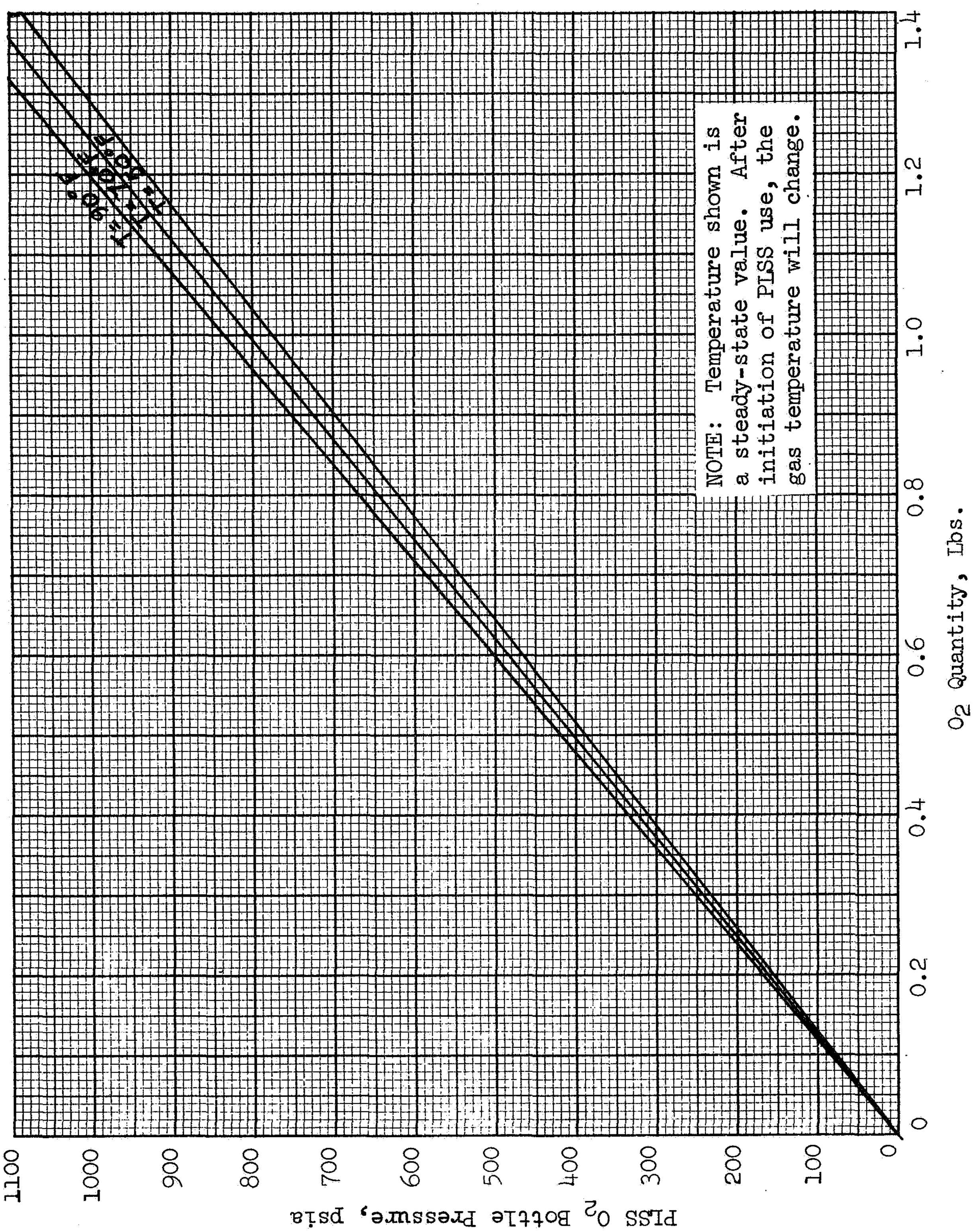


Figure 4.5-59 O_2 Bottle Pressure Vs. O_2 Quantity

4.6 OPS

The OPS is required to provide pressure control for all operational modes. When used during purge mode, it also provides contaminant control. Although the system is not required to provide thermal control, some metabolic heat can be absorbed depending upon the dew point temperature at the purge port, the flow rate, and the temperature rise across the PGA as shown in Figures 4.6-1 and 4.6-2. Figure 4.6-2.1 shows the crewman heat storage at various metabolic rates with OPS purge.

4.6.1 Oxygen Supply

When the OPS oxygen supply is fully charged, the supply pressure varies with temperature as shown in Figure 4.6-3. From the time of charging until mission use, the OPS supply pressure will vary as noted on Figure 4.6-3.1. The oxygen quantity (mass) as it relates to bottle pressure at various steady state gas temperatures is shown in Figure 4.6-3.2. The actual supply pressure is displayed by the OPS bottle pressure gage whose accuracy and configuration is shown in Figure 4.6-4. With the OPS mounted on the suit, and during the purge mode of OPS operation, the bottle pressure can be monitored by the crewman. The duration of the OPS oxygen is dependent upon the oxygen usage rate as shown in Figure 4.6-5. The bottle pressure decay during this mode, with a nominal flow rate of 8.0 lb/hr, will be similar to that shown in Figure 4.6-6, and with a flow rate of 4.2 lb/hr, will be as shown in Figure 4.6-6.1. Figure 4.6-7 shows the O_2 flow rate through the purge valve during purge valve operation, at high flow position, as a function of the suit pressure. The OPS blowdown time as a function of the supply pressure is given in Figure 4.6-8. The PGA pressure variation with time for a partial blowdown with failed open OPS regulator is shown in Figure 4.6-8.1 (results of a single test only).

4.6.2 Oxygen Supply Residuals

The residual oxygen in the OPS for the make-up mode of operation is 0.106 lb which corresponds to a pressure 100 psia at a temperature of 64° F. The residual oxygen for the 8.4 lb/hr purge mode of operation is 0.773 lb which corresponds to a pressure of 500 psia at a temperature of -60° F. The residual oxygen for the 4.2 lb/hr purge mode is 0.445 lb, which corresponds to a pressure of 300 psia at -60° F. (The -60° F temperatures refer to the gas temperatures in the OPS storage bottles.)

4.6.3 Oxygen Pressure Regulation

The regulator outlet pressure as a function of the supply pressure and ambient pressure is shown in Figure 4.6-9. The OPS pressure regulator characteristics as a function of supply pressure, supply temperature, and flow rate are shown in Figures 4.6-10 and 4.6-11. The performance of the OPS regulator can be verified during OPS checkout by monitoring the regulator checkout pressure gage which possesses the accuracy characteristics and configuration as shown in Figure 4.6-12. The OPS checkout orifice characteristics and bleed-down times are shown in Figures 4.6-13 and 4.6-14.

The pressure regulation is controlled by a metallic bellows. The pressure is referenced to ambient by means of an orifice in the bellows. In the unlikely event of a leak in the bellows, the flow rate of the PGA oxygen through the orifice versus the bellows inlet pressure will be as shown in Figure 4.6-17.

4.6.4 Temperature Control

There are no temperature control devices in the OPS, except thermal insulation, because they are not needed. The regulator outlet, helmet duct, and crewman temperatures versus OPS discharge time are shown in Figures 4.6-15 and 4.6-16 for the warm and cold initial O_2 supply conditions, respectively.

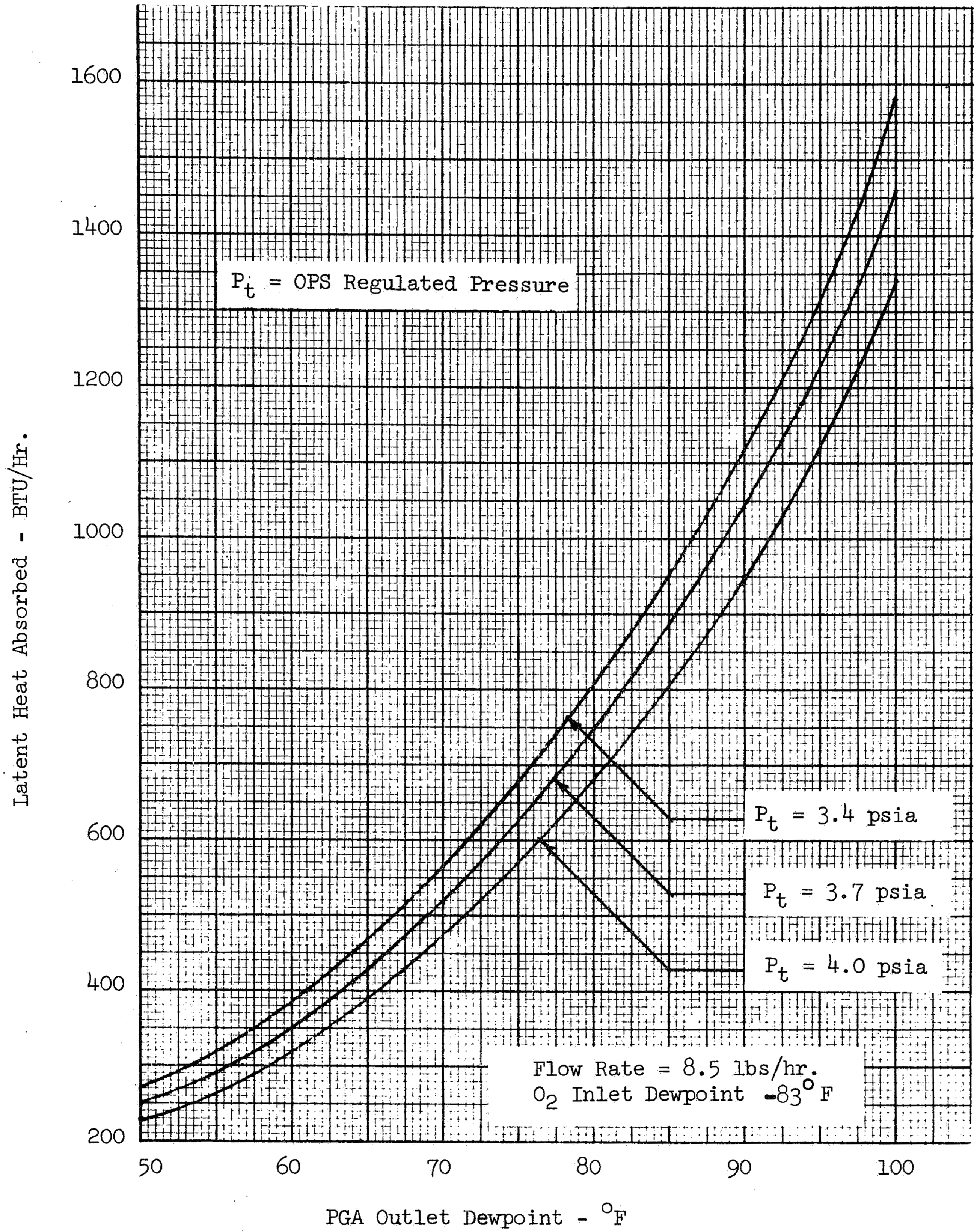


Figure 4.6-1A Latent Heat Absorbed Vs. PGA Outlet Dewpoint

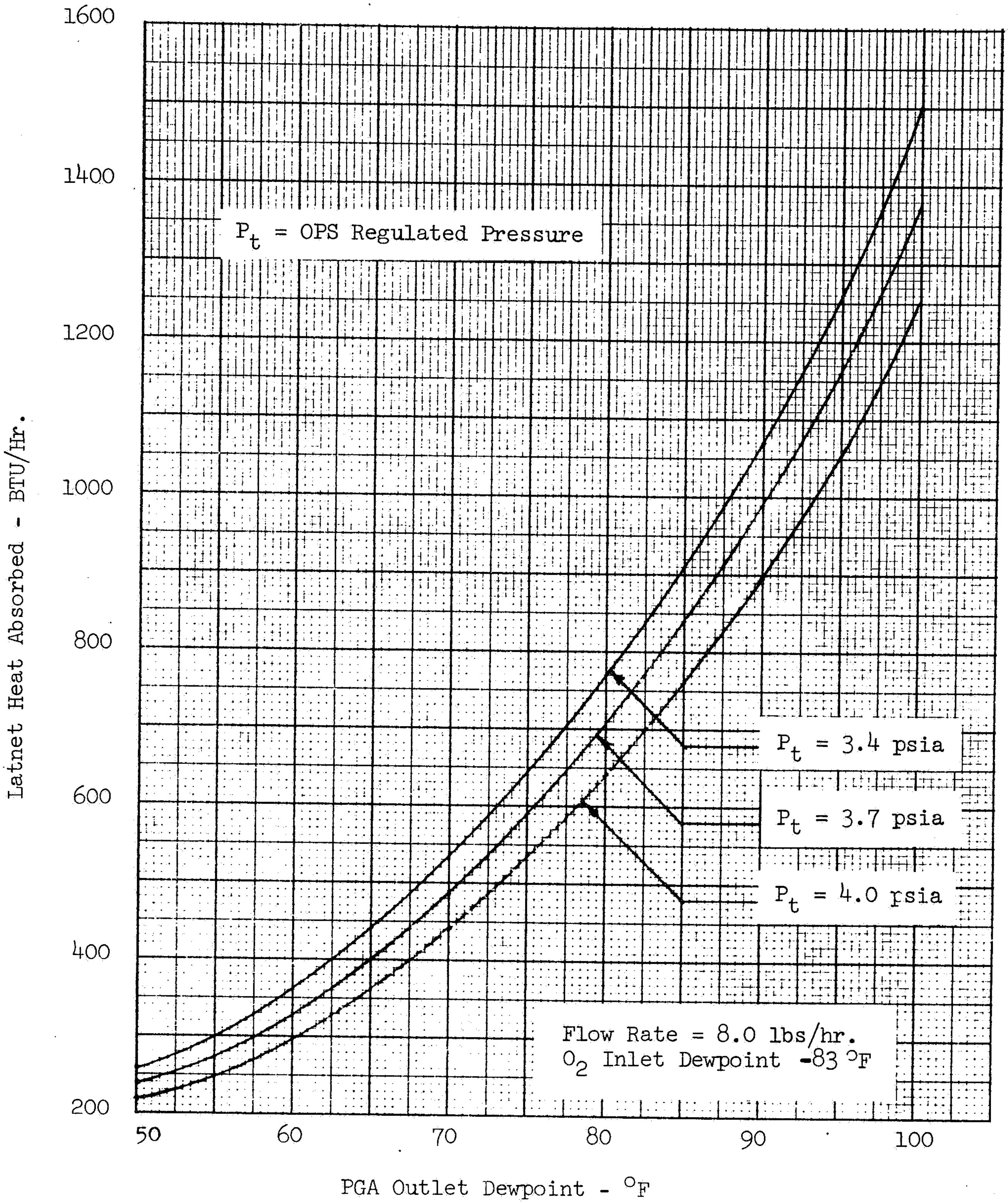


Figure 4.6-1B Latent Heat Absorbed Vs. PGA Outlet Dewpoint

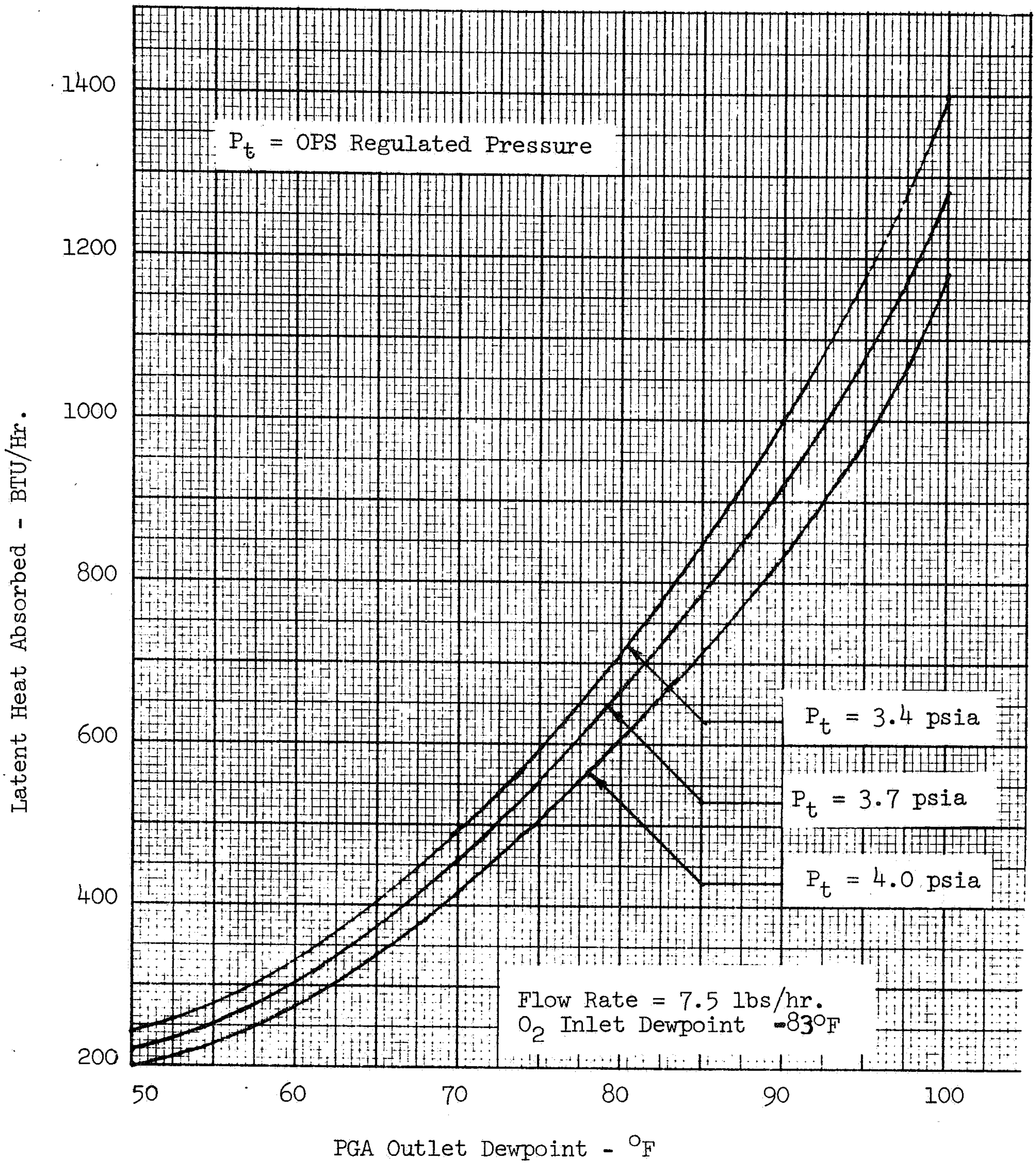


Figure 4.6-1C Latent Heat Absorbed Vs. PGA Outlet Dewpoint

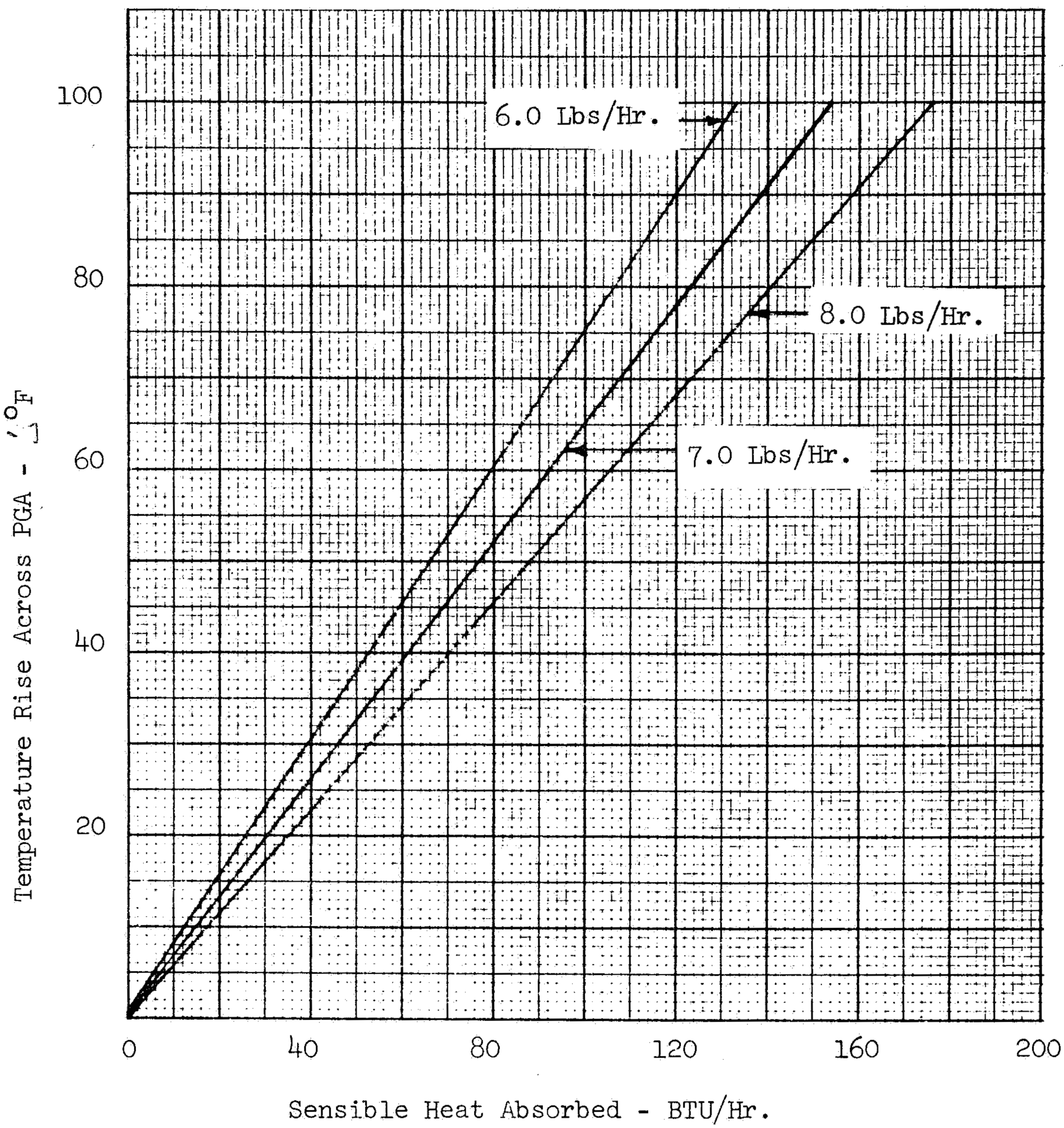


Figure 4.6-2 OPS Sensible Heat Absorption Capabilities

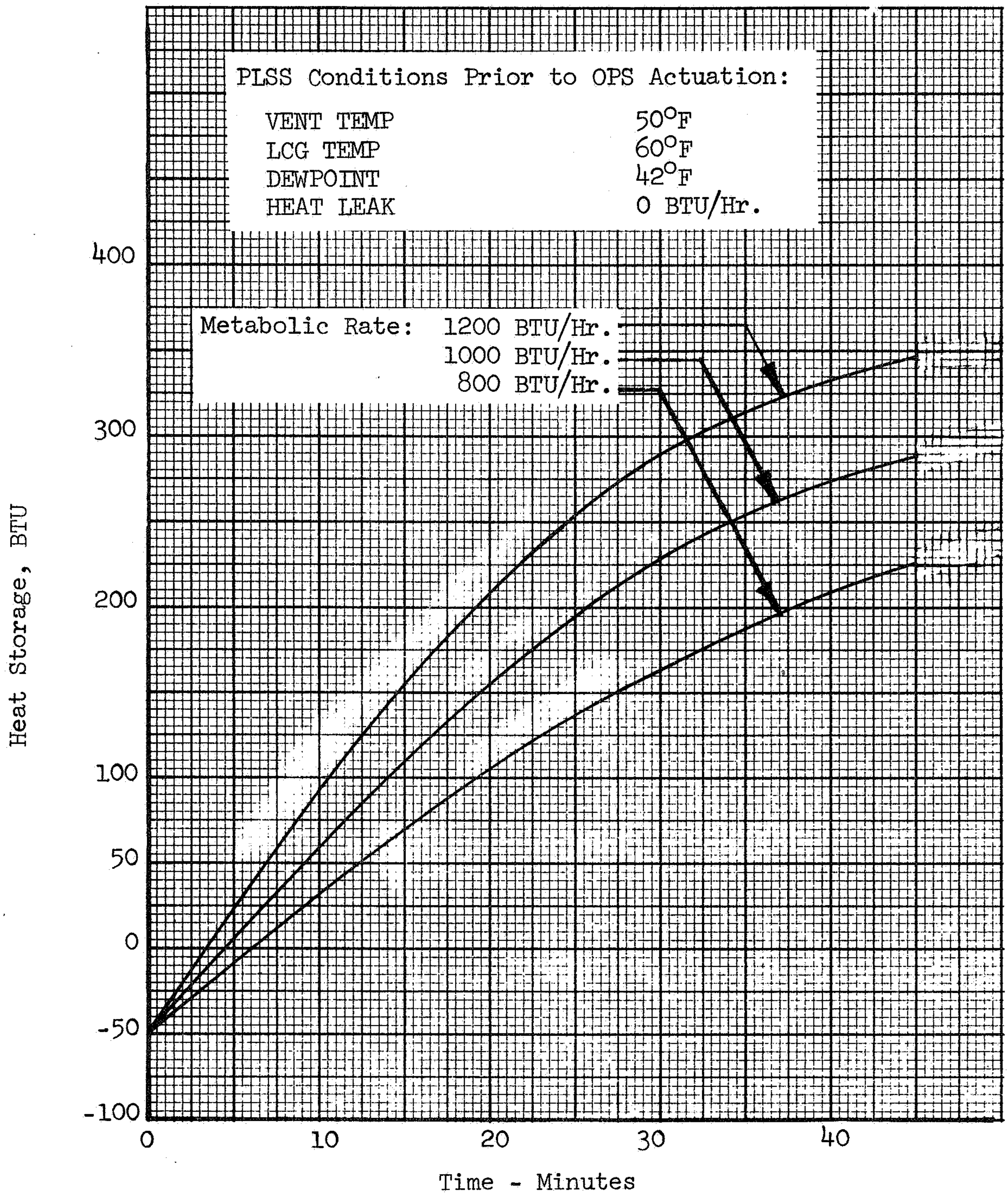


Figure 4.6-2.1 Crewman Heat Storage Vs. Time

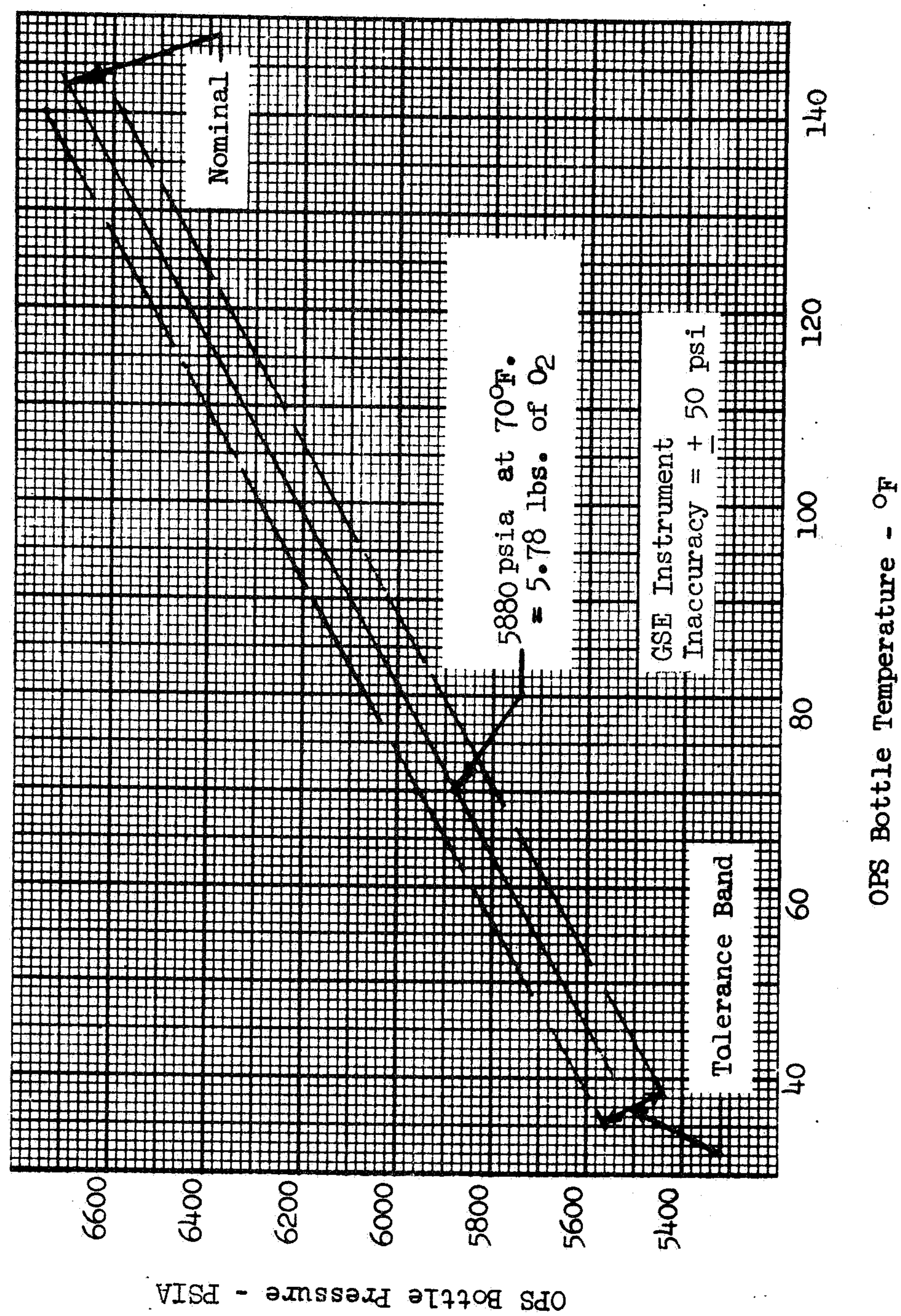


Figure 4.6-3 OPS Bottle Temperature Vs. Pressure - Ground Charging

NOTE: OPS LEAKAGE

1. Spec. Max. = 20 scc/Hr.
   Equivalent to 0.075 psia/Hr.
2. Temp. Effects are not significant because of low leakage rate.
3. For regulator checkout, bottle pressure will degrade at approx. 24 psia/checkout for the following conditions:
   A. OPS Pressure = 5000-6000 psia
   B. Temp. = 70°F
   C. Flow = 0.48 Lbs/Hr. for 3 Min.

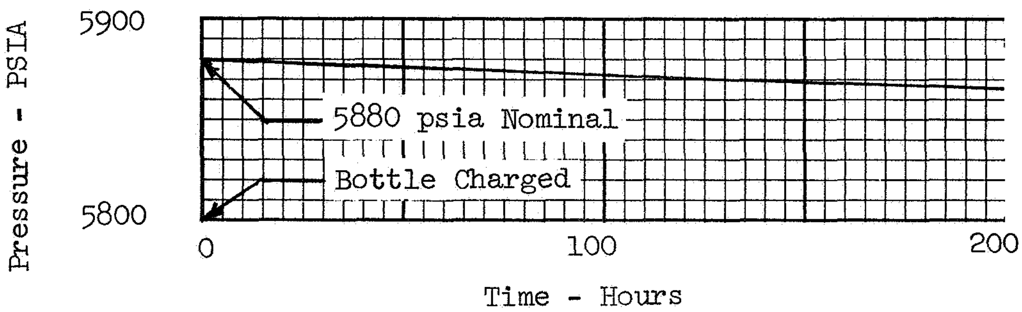


Figure 4.6-3.1 OPS Oxygen Bottle Pressure Vs. Stowage Time

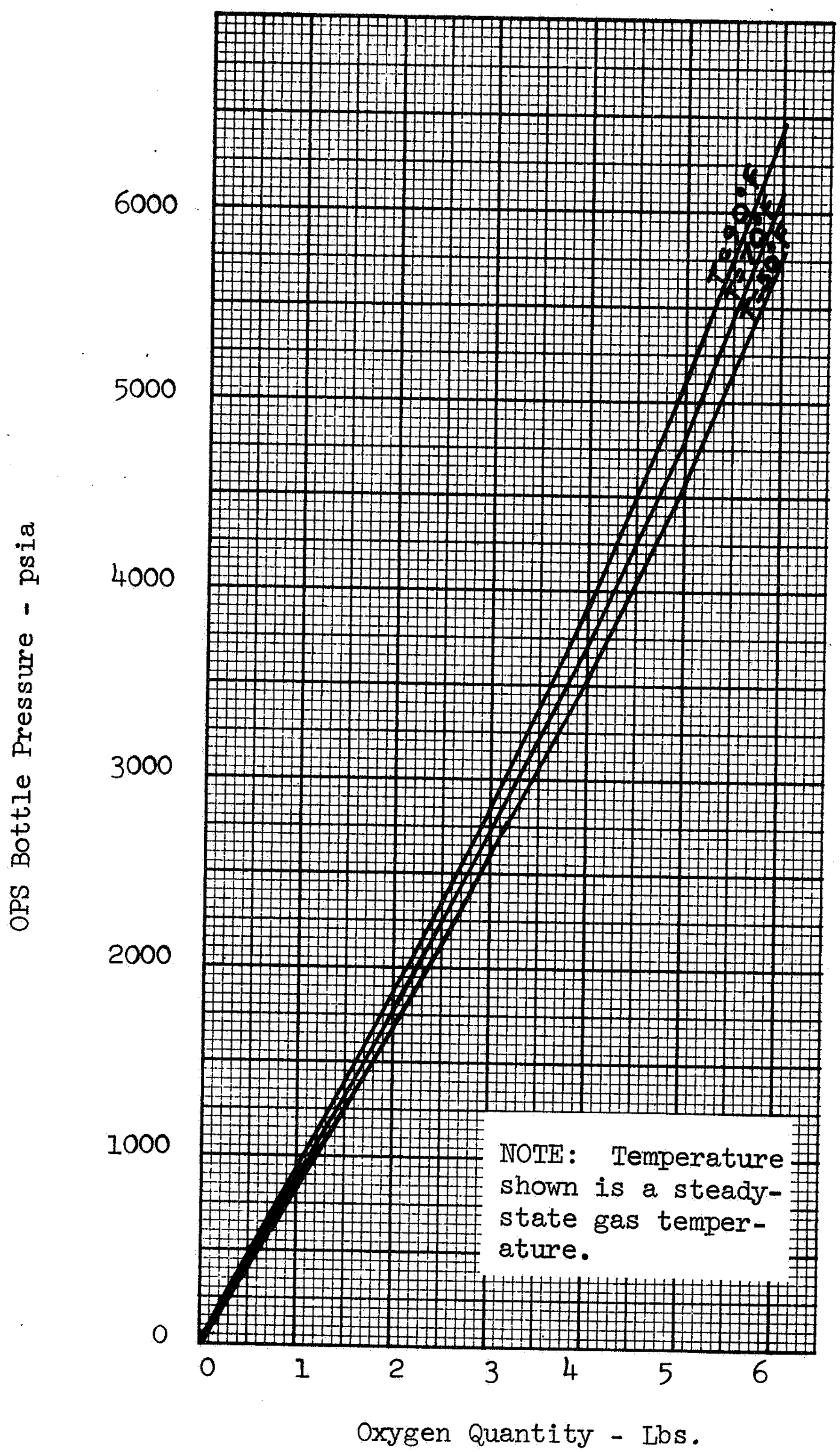


Figure 4.6-3.2 OPS O_2 Bottle Pressure Vs. Oxygen Quantity

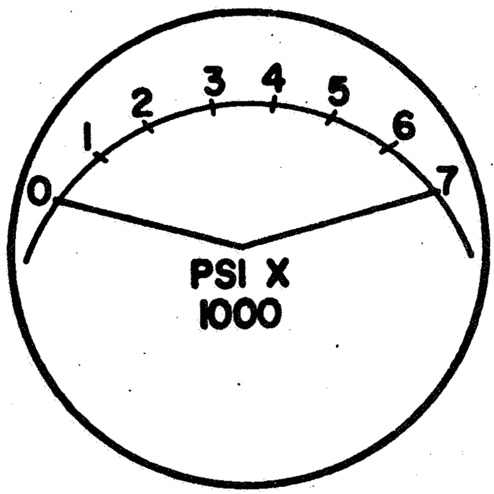


Figure 4.6-4 Oxygen Purge System High Pressure Oxygen Gage

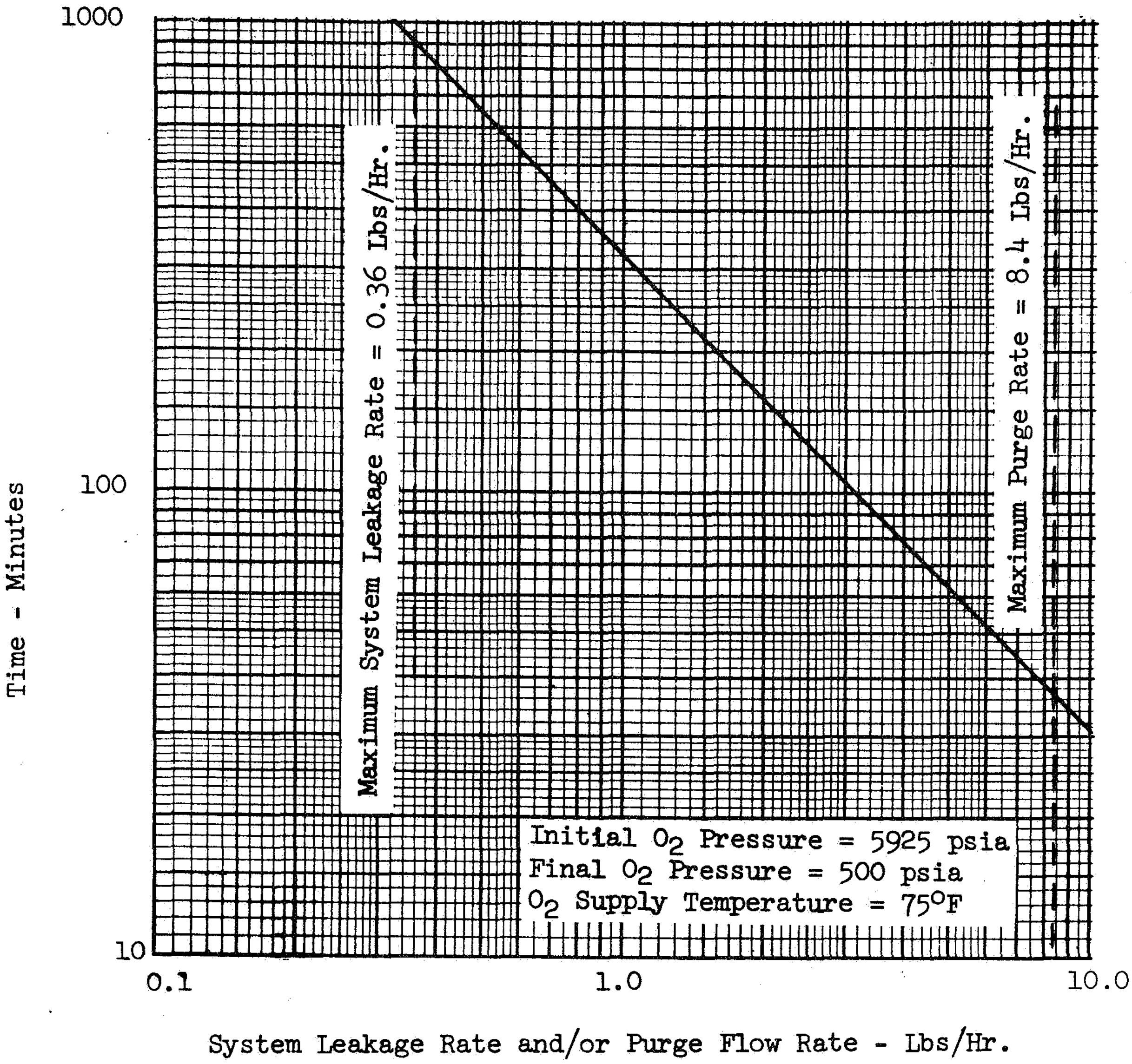


Figure 4.6-5 OPS Oxygen Supply Duration Vs. Usage Rate

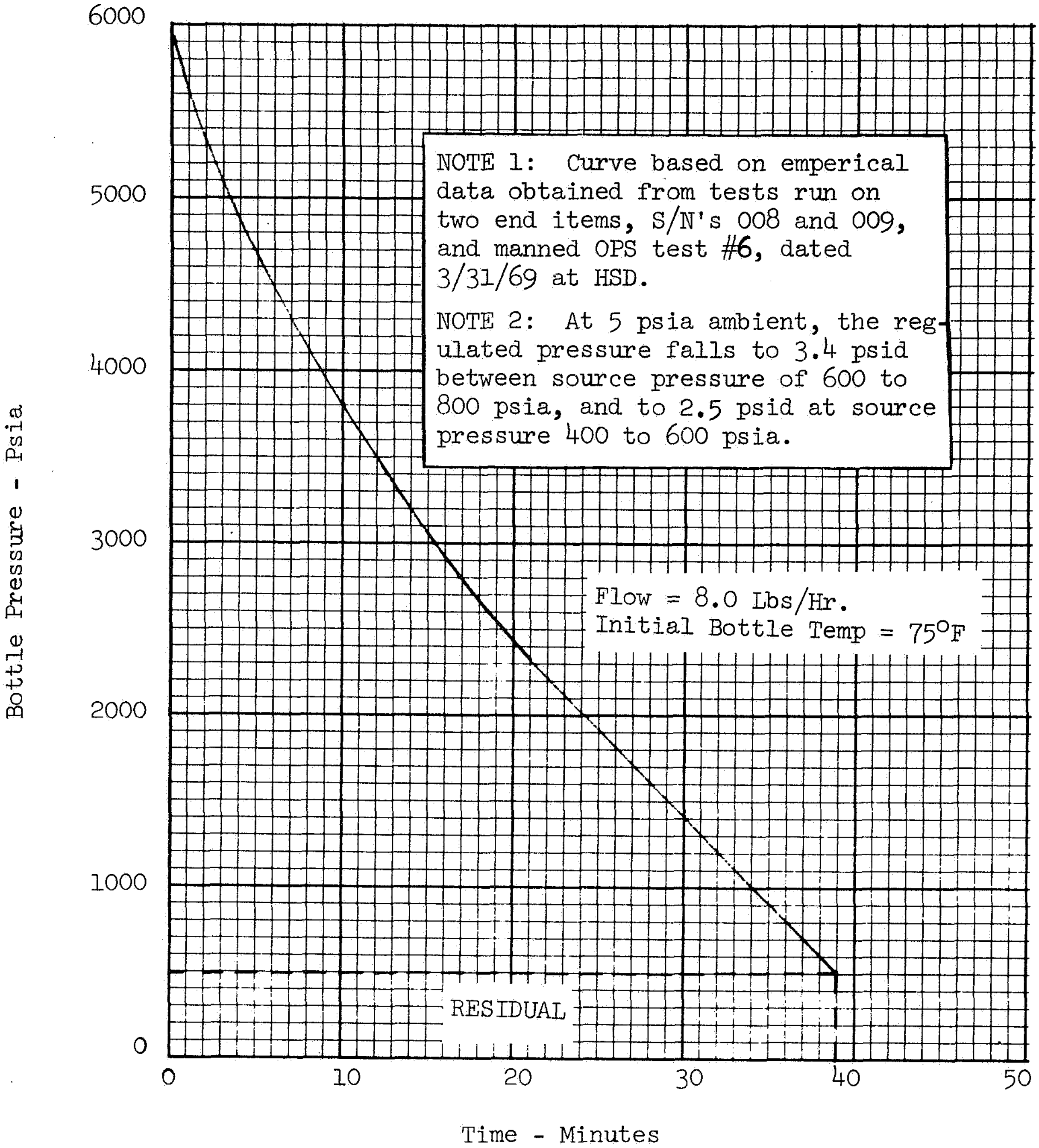


Figure 4.6-6 OPS Bottle Pressure Decay Vs. Purge Time

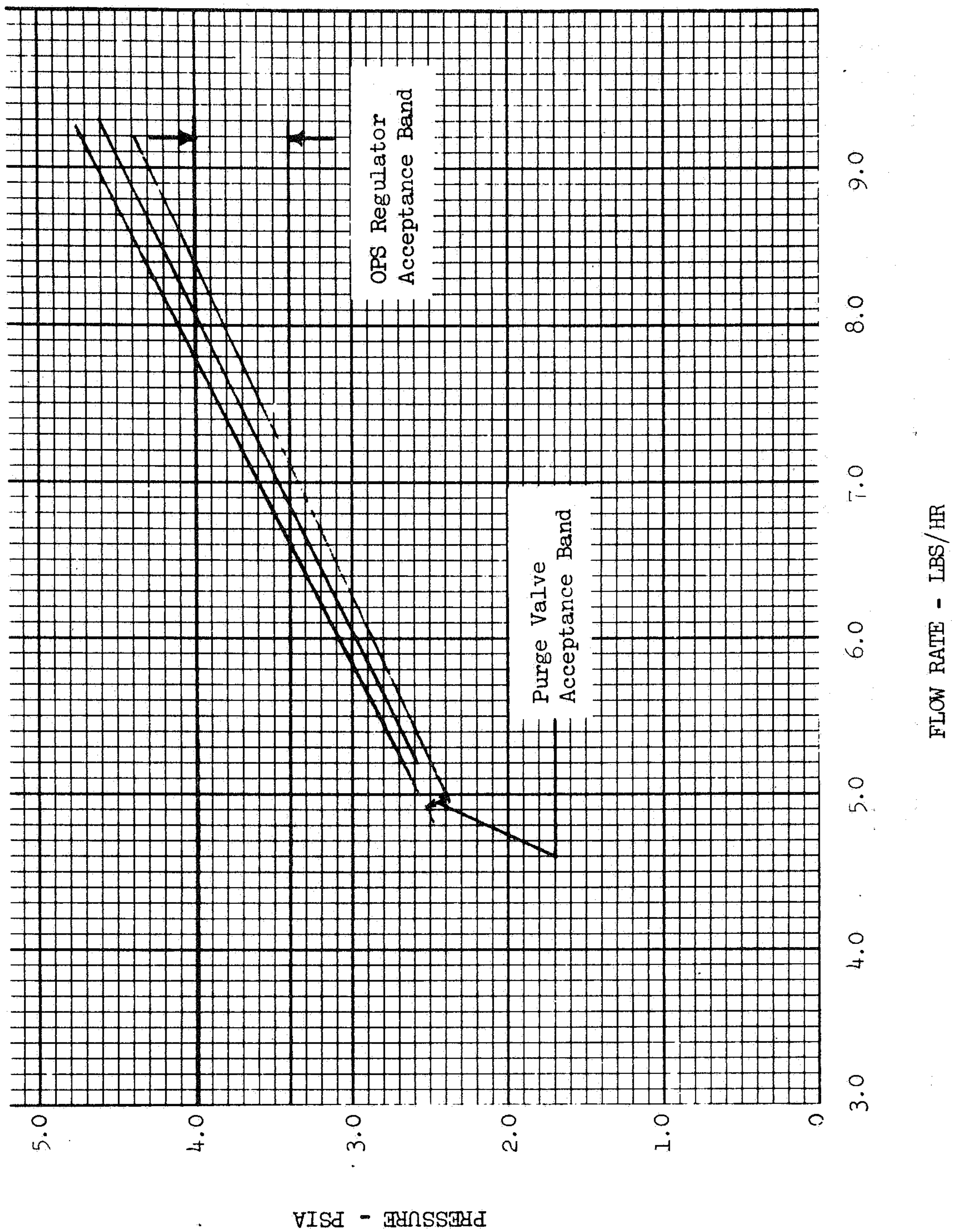


Figure 4.6-7 OPS FLOW RATE VERSUS PRESSURE AS DICTATED BY PURGE VALVE

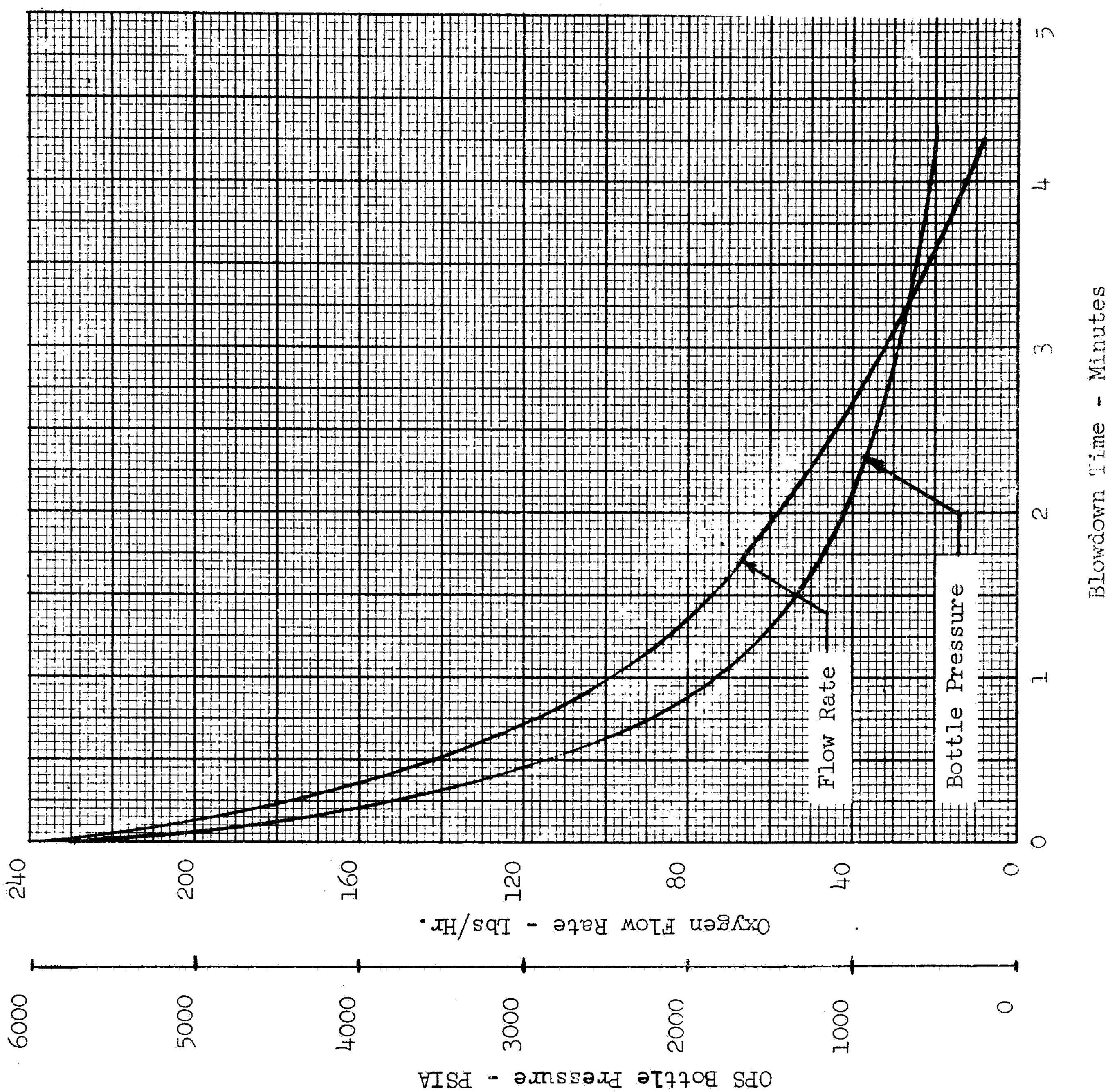


Figure 4.6-8 OPS Bottle Pressure and Flow Rate
Vs. Blowdown Time - Full Open Reg.

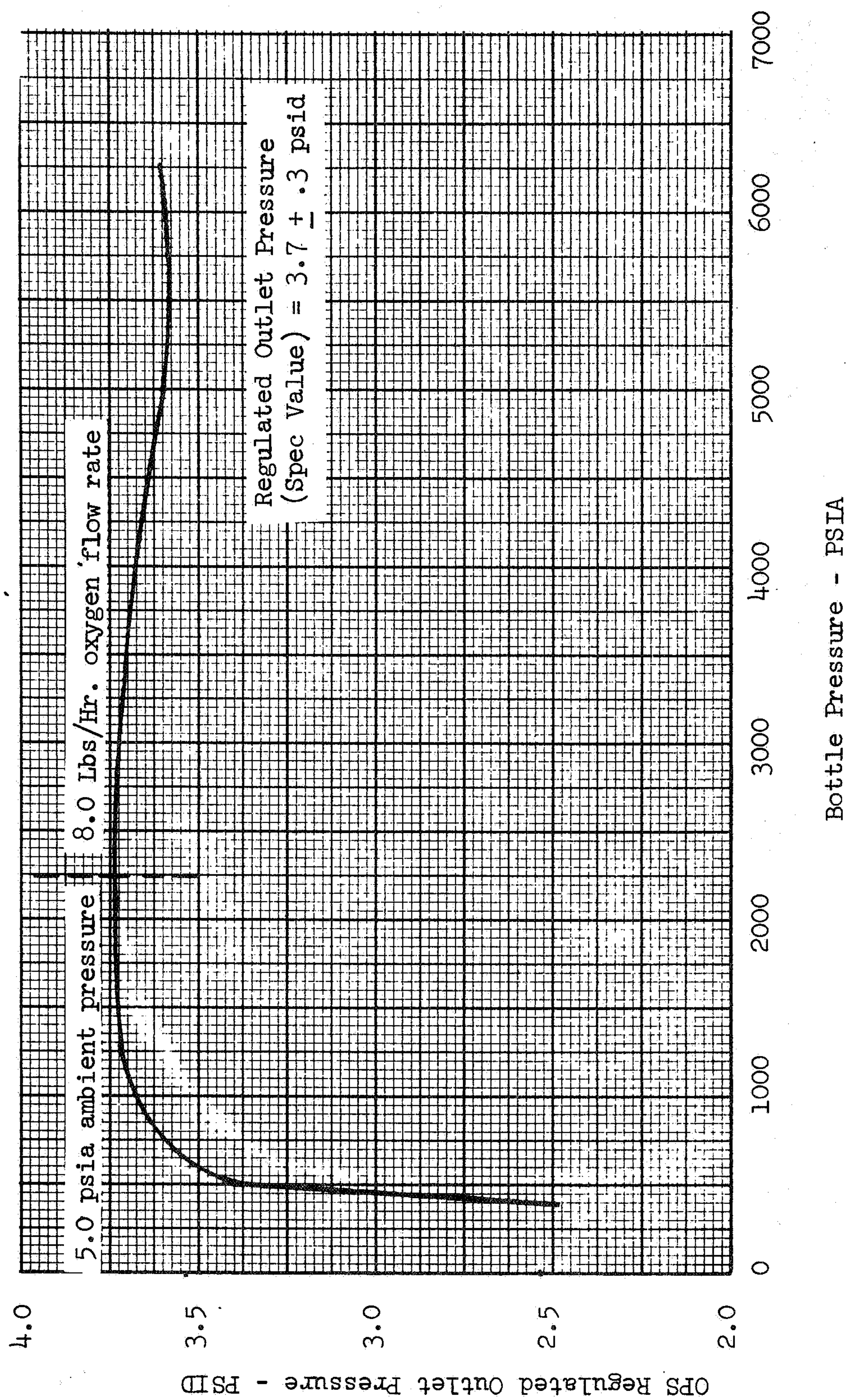


Figure 4.6-9 OPS Regulated Outlet Pressure Vs. Source Pressure

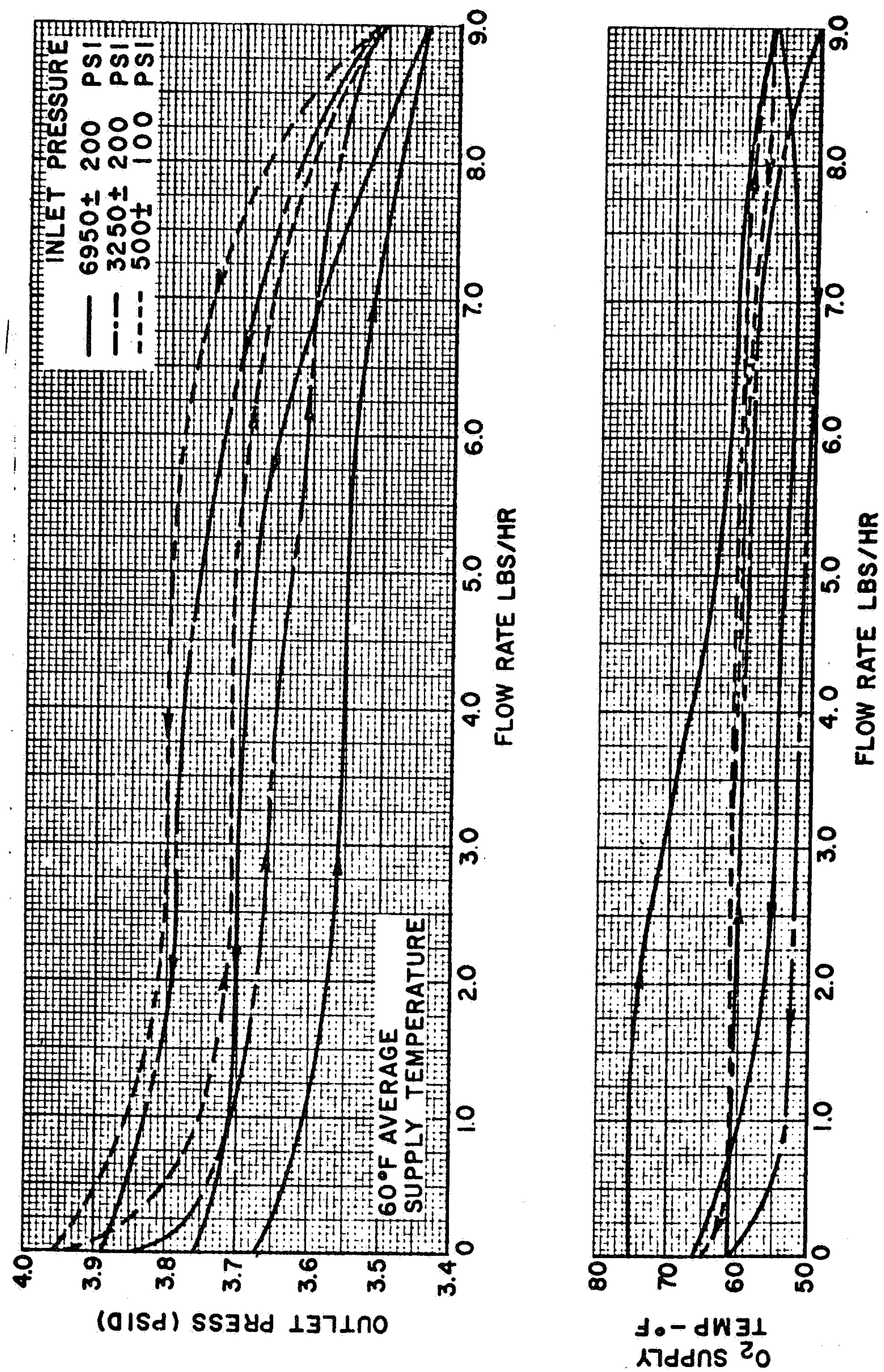


Figure 4.6-10 OPS O_2 Supply Temperature and Outlet Pressure Versus Flow (60^{o} Average Supply Temperature)

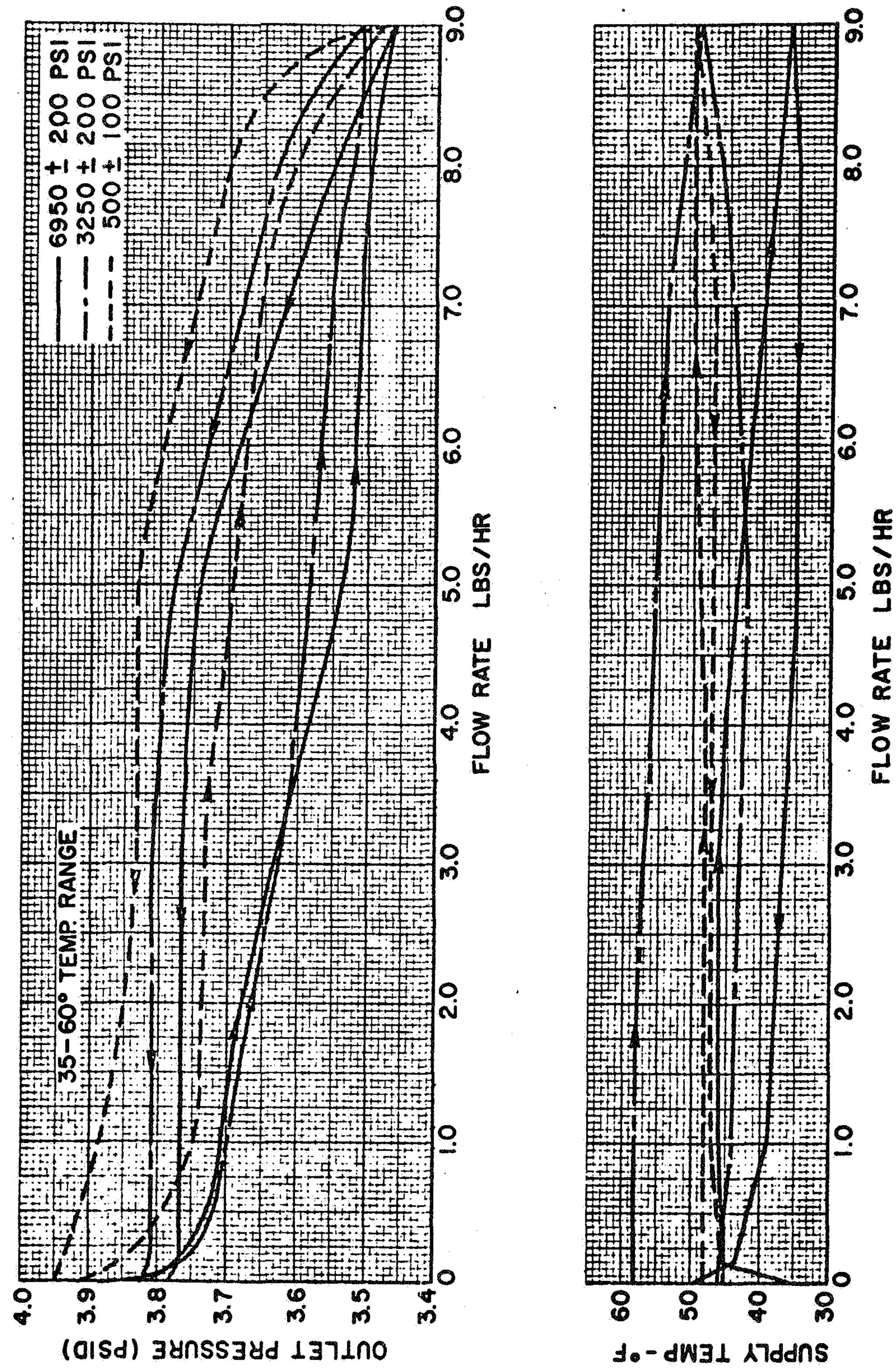
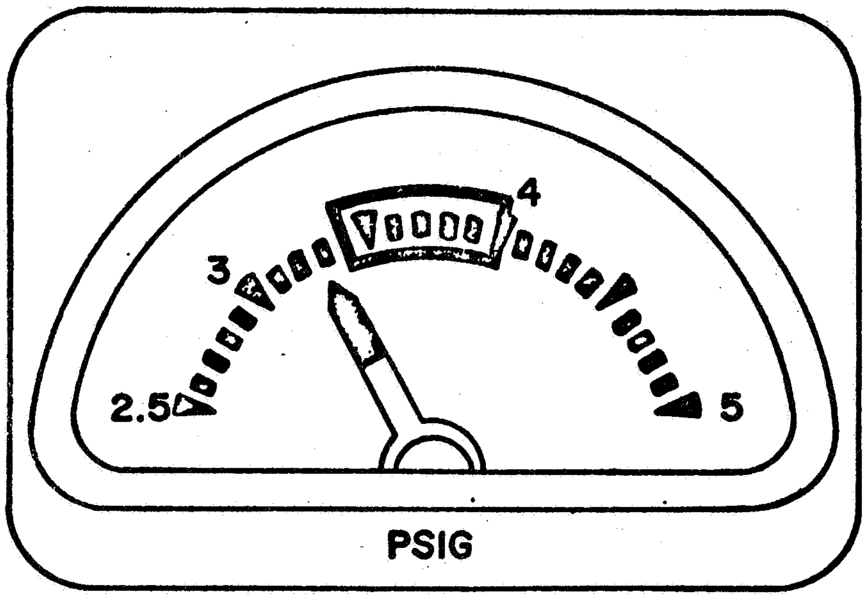


Figure 4.6-11 OPS O_2 Supply Temperature and Outlet Pressure Versus Flow (35 - 60° Temperature Range)



ACCURACY ± 0.1 PSIG

Figure 4.6-12 Oxygen Purge System Low Pressure Checkout Gage

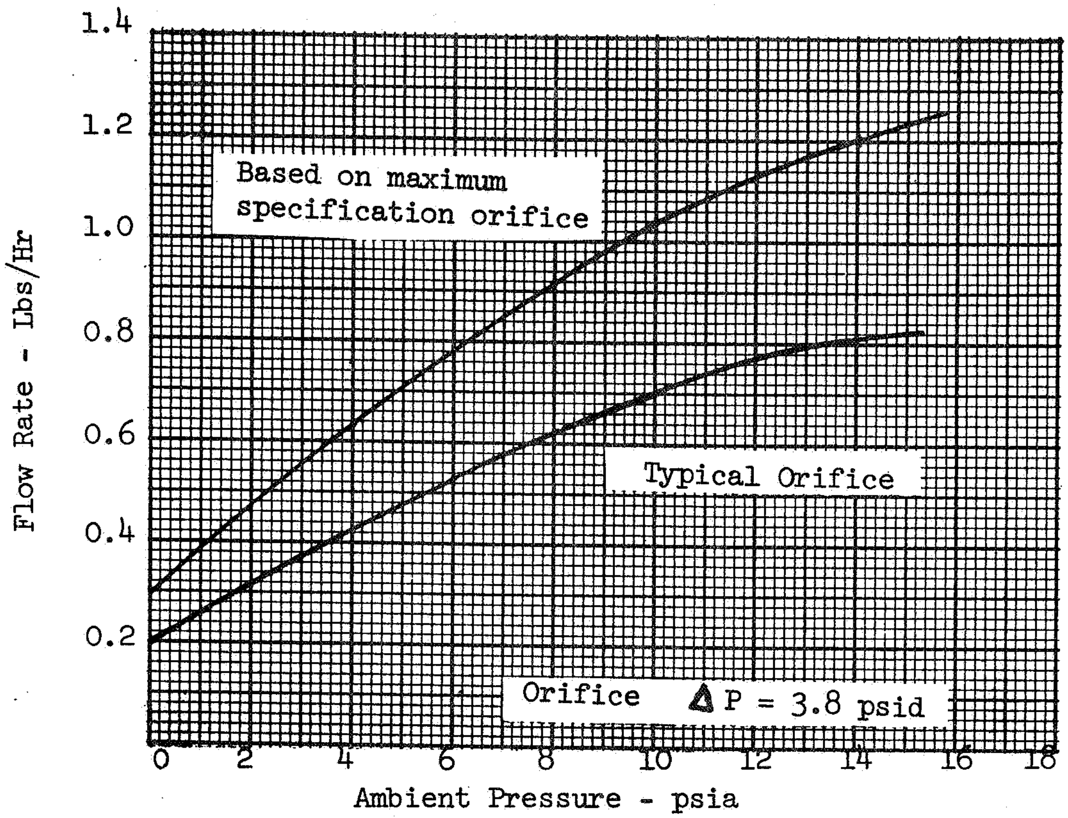


Figure 4.6-13 OPS Checkout Orifice Characteristics

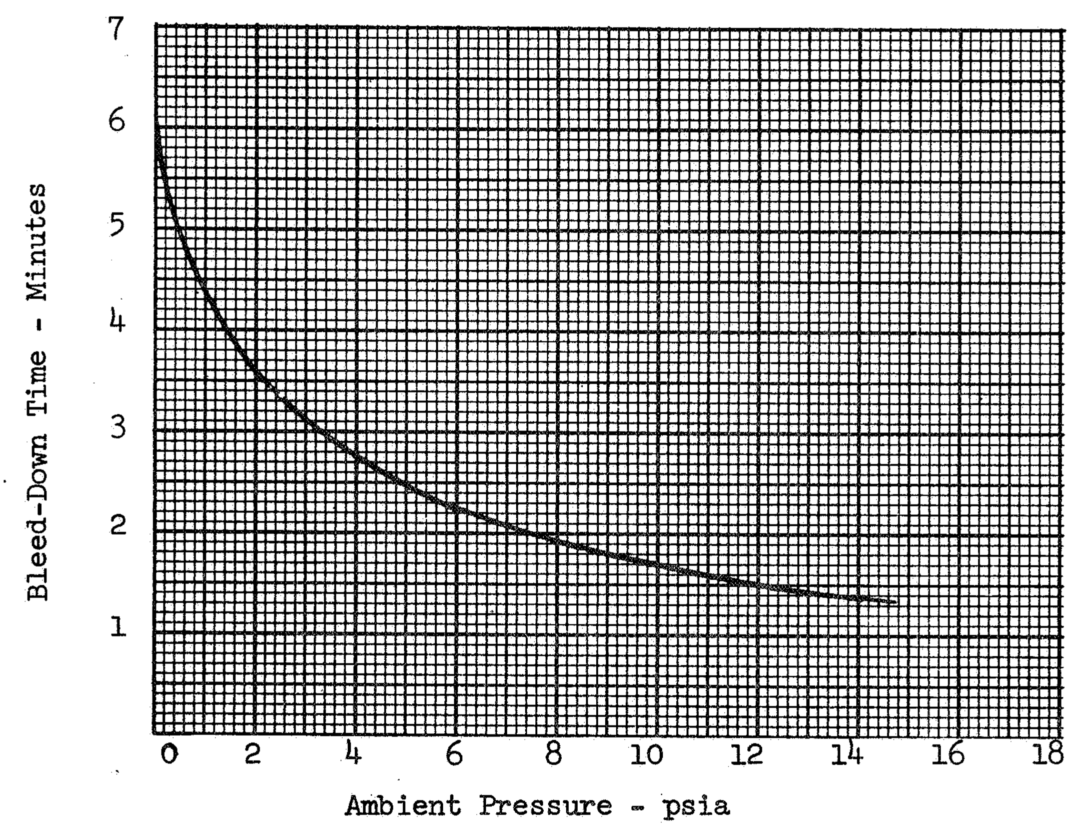


Figure 4.6-14 OPS Checkout Orifice Bleed-Down Time

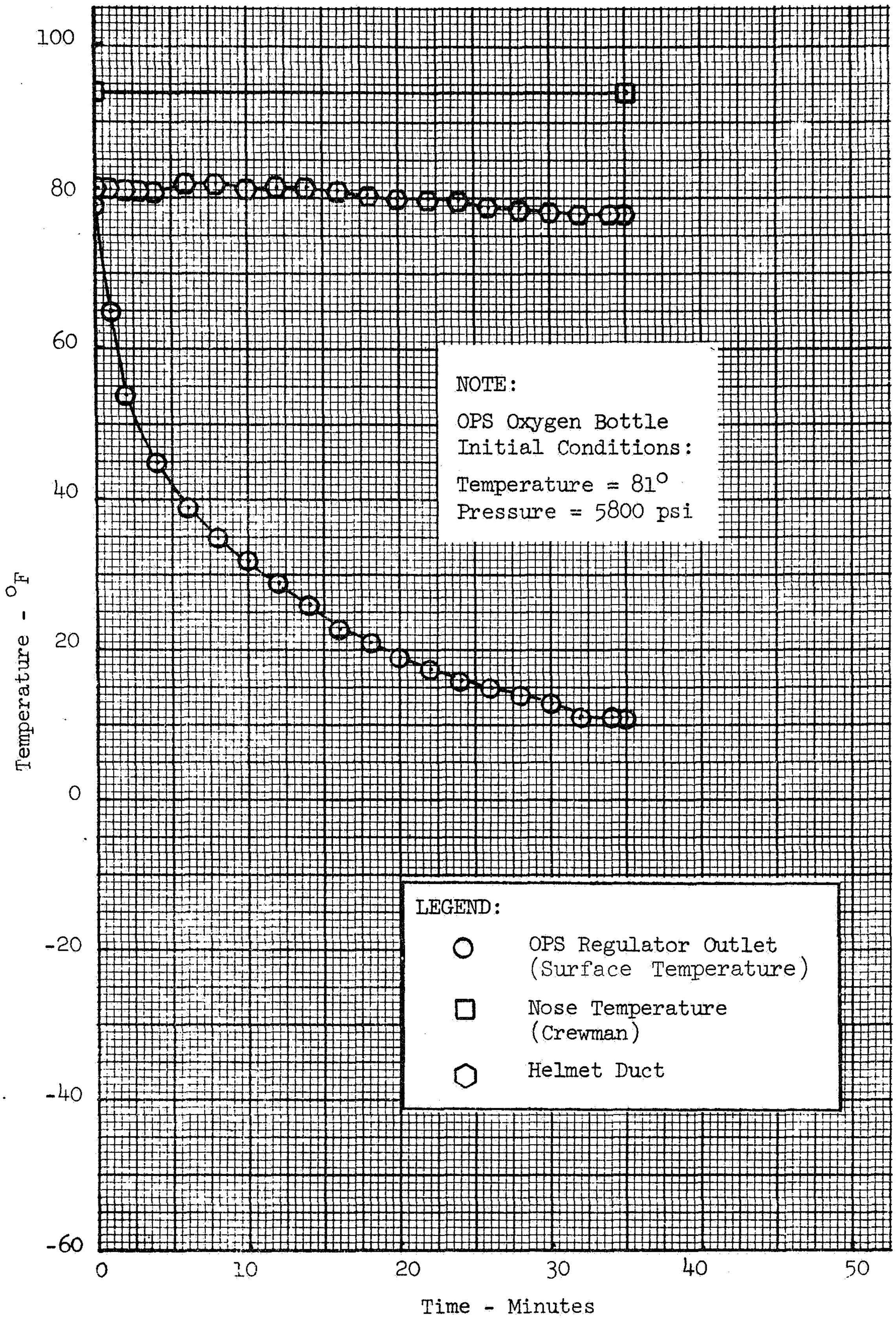


Figure 4.6-15 Regulator Outlet, Helmet Duct, and Crewman Temperatures Without OPS Heater Vs. Time (Warm Condition)

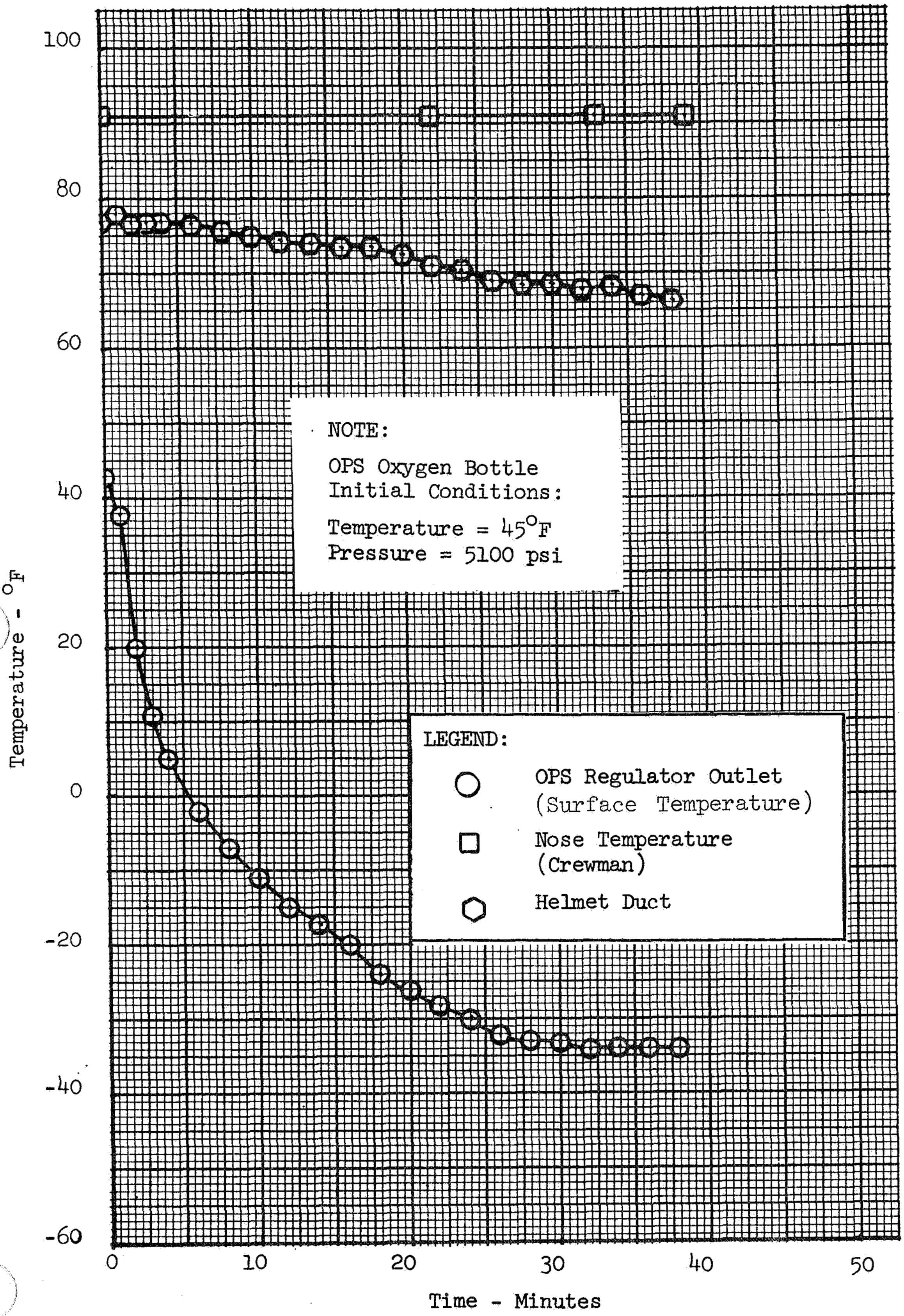


Figure 4.6-16 Regulator Outlet, Helmet Duct, and Crewman Temperatures Without OPS Heater Vs. Time (Cold Condition)

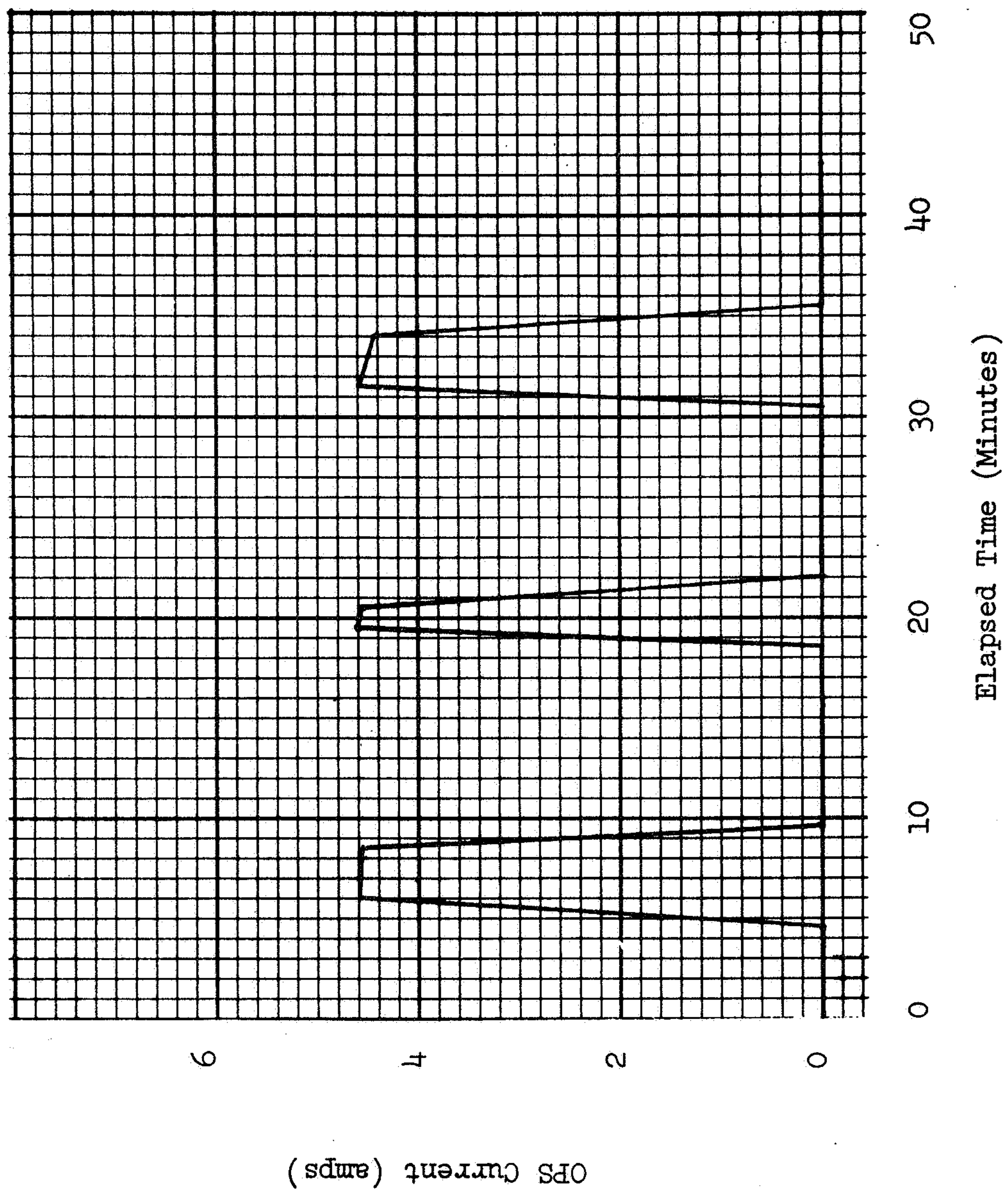


Figure 4.5-17 OPS Battery Current Vs. Time (Typical Purge Operation)

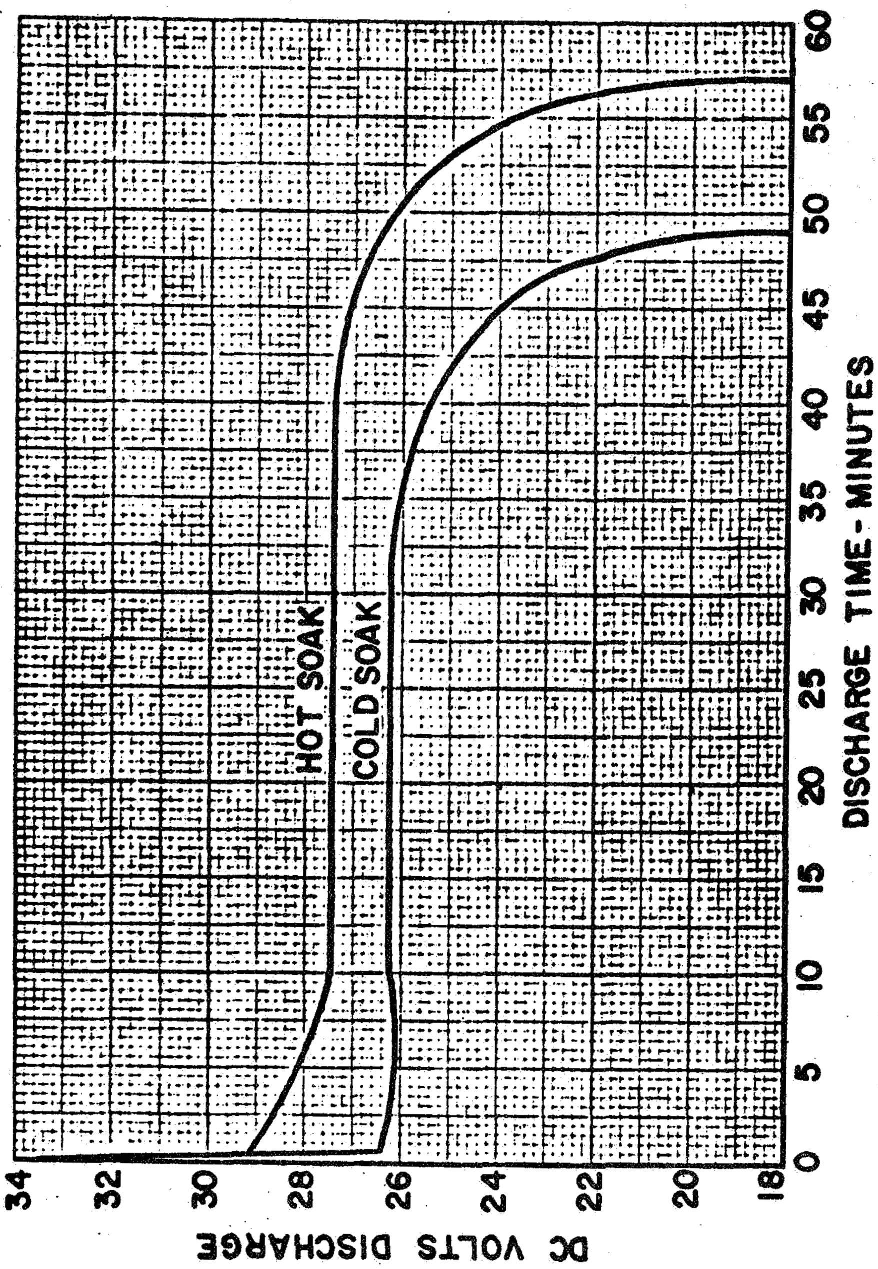


Figure 4.6-18 OPS Battery Discharge Characteristics

Table 4.6-1 OPS Power Supply Storage and Usage Time - Temperature Limitations

CONDITION OF POWER SUPPLY	TEMPERATURE LIMITATIONS	TIME AT TEMPERATURE LIMITATIONS
Storage, unactivated	40 - 100°F	1 year maximum
Storage, activated		24 days total life
(a)	60 - 90°F	24 days maximum
(b)	40 - 60°F 90 - 110°F	6 days maximum
(c)	110 - 130°F	4 days maximum
Operation	35 - 130°F	

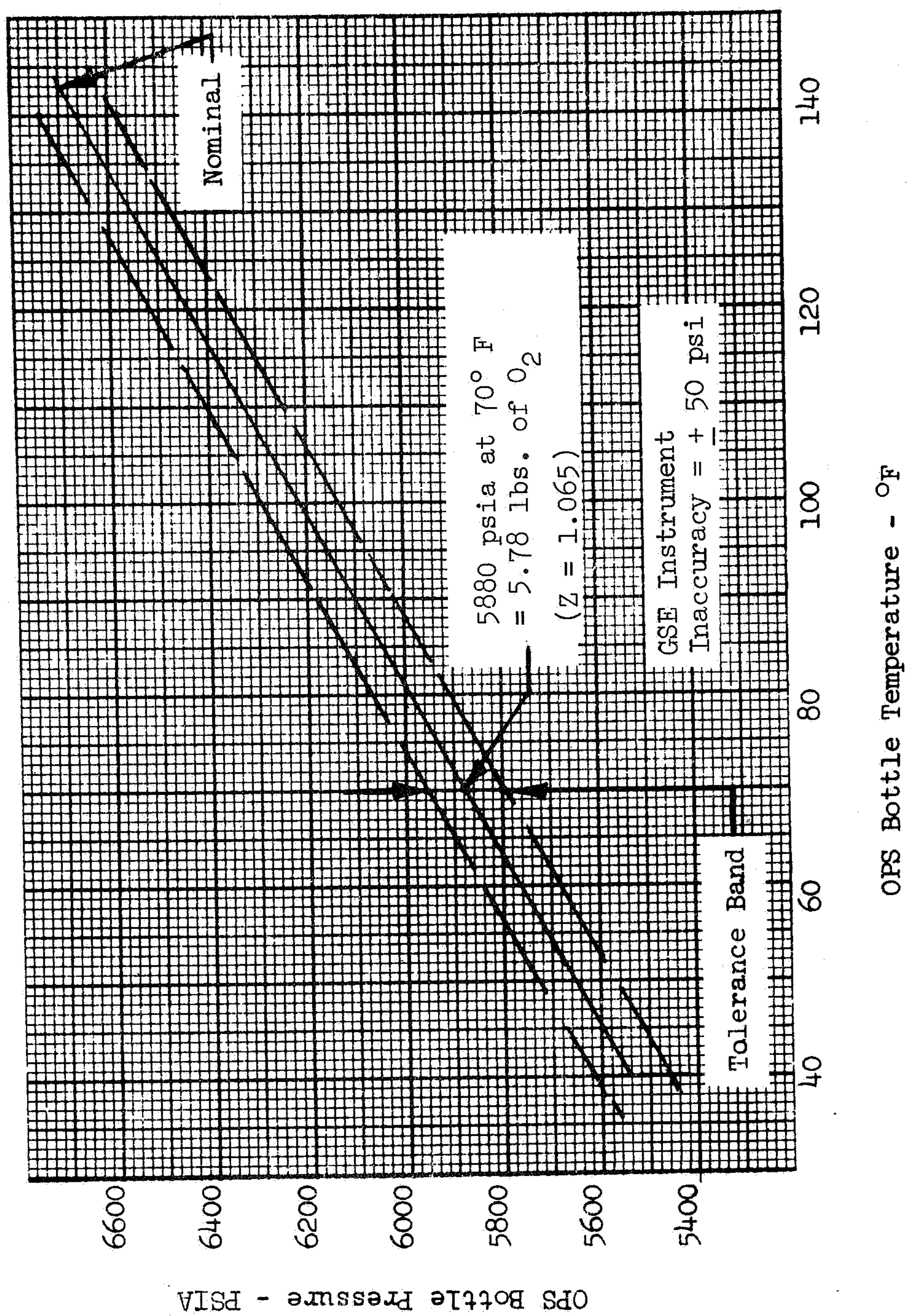


Figure 4.6-3 OPS Bottle Temperature Vs. Pressure - Ground Charging

NOTE: OPS LEAKAGE

1. Spec. Max. = 20 scc/Hr.
   Equivalent to 0.075 psia/Hr.
2. Temp. Effects are not significant because of low leakage rate.
3. For regulator checkout, bottle pressure will degrade at approx. 24 psia/checkout for the following conditions:
   A. OPS Pressure = 5000-6000 psia
   B. Temp. = 70°F
   C. Flow = 0.48 Lbs/Hr. for 3 Min.

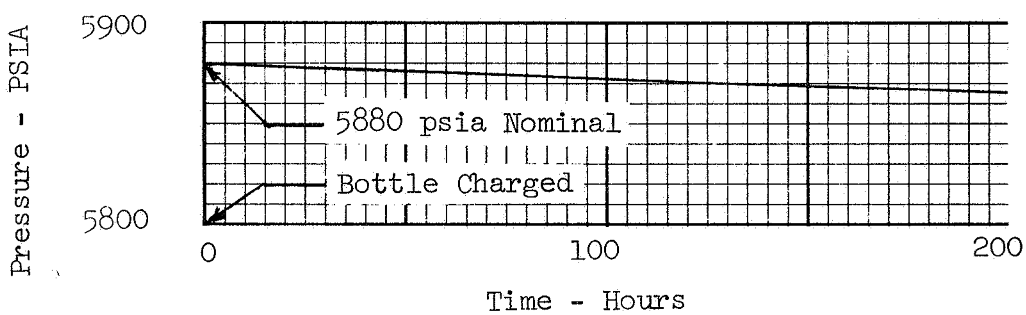


Figure 4.6-3.1 OPS Oxygen Bottle Pressure Vs. Stowage Time

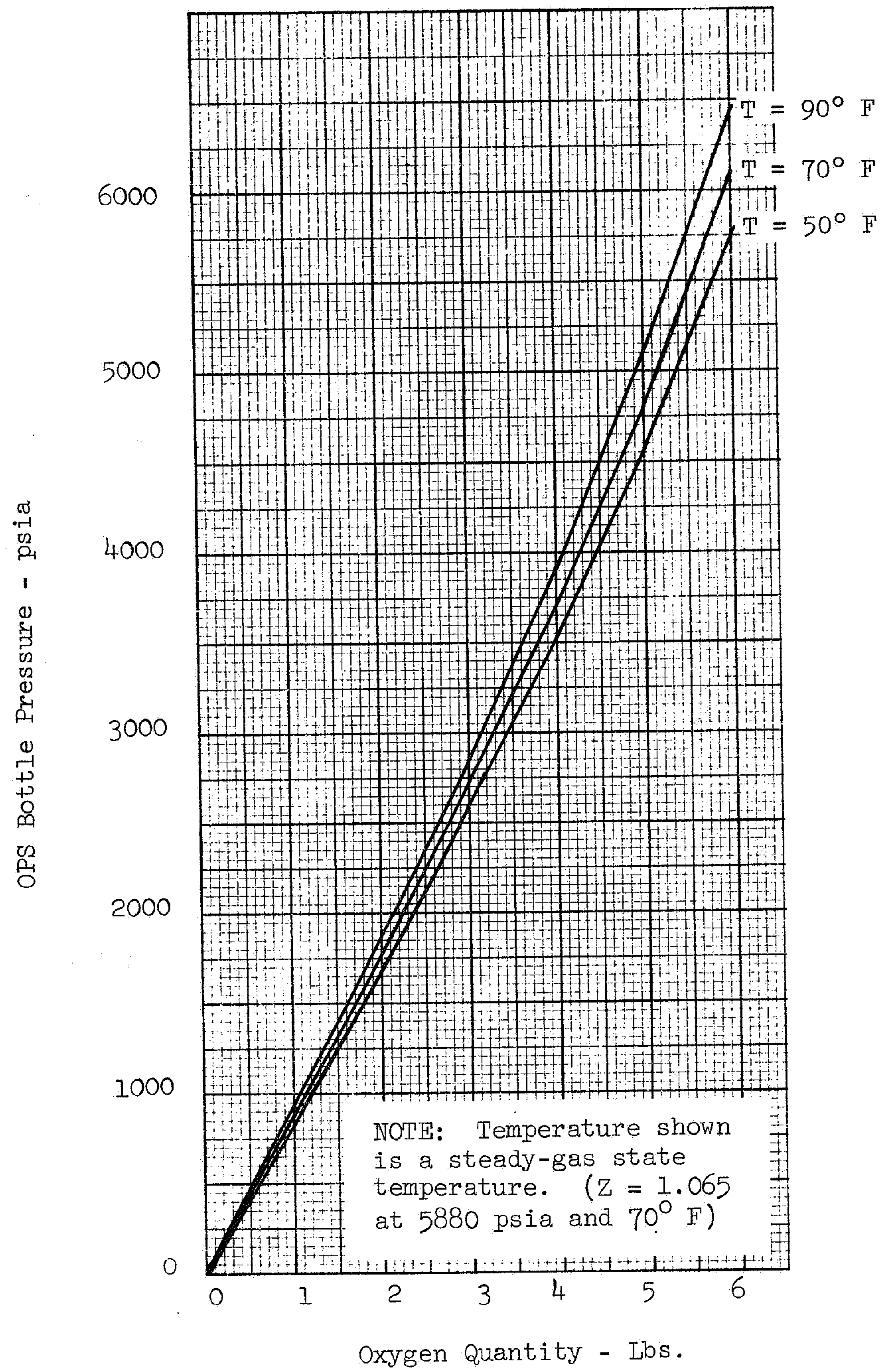
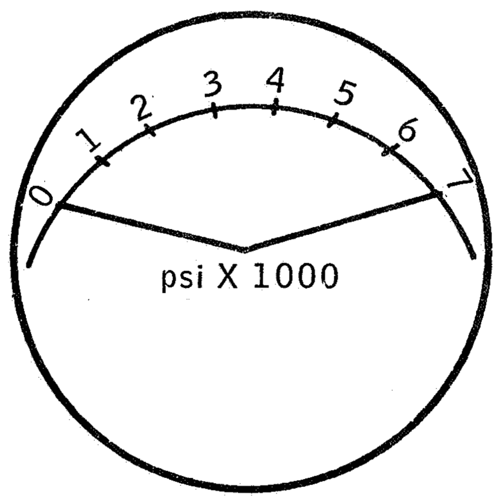


Figure 4.6-3.2 OPS O_2 Bottle Pressure Vs. Oxygen Quantity



Accuracy ± 300 psia

Figure 4.6-4 Oxygen Purge System High Pressure Oxygen Gage

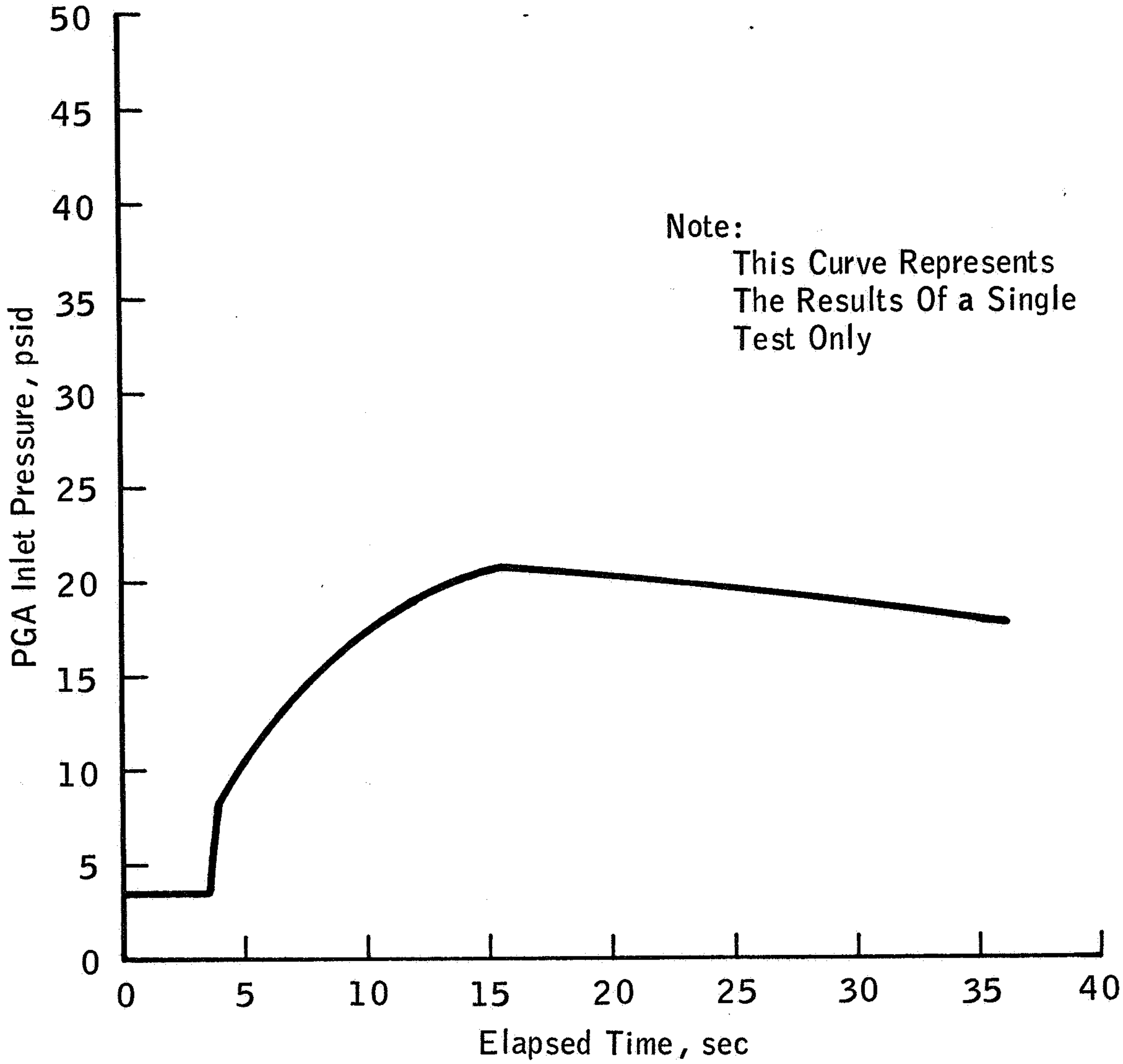


Figure 4.6-8.1 Suit Inlet Pressure Versus Time -
Failed Open OPS Regulator

G MISSION APPENDIX

APOLLO 11

Equipment Assignment Maxtrix and Appendix Data Location

Crewman / Equipment	CMP		LMP		CDR	
	S/N	Page	S/N	Page	S/N	Page
PLSS*	---	---	014	G-3	015	G-22
OPS*	---	---	008	G-10	013	G-29
PGA	033	G-2	077	G-11	056	G-30
LCG	---	---	079	G-12	077	G-31
EVCS**	---	---	EVC-2 1967B	---	EVC-1 1966B	---
LEVA*	---	---	006	---	005	---
Purge Valve*	---	---	157	G-13	155	G-32
Consumables	---	---	---	G-14	---	G-33

* Interchangeable between crewmen

** Communications data combined with PLSS data

Amendment
7/16/69

APOLLO 11

FLIGHT PGA CHECKOUT DATA

COLLINS
CREWMAN

A7L-033
PGA S/N

ITEM	SPEC. REQUIREMENT	FACTORY PDA	CAT PIA	FLIGHT PIA	FLIGHT DAY	REMARKS
Relief Valve	S/N N/A					
Crack	5.5 psi	N/A	N/A	N/A		
Reseat	4.8 psi	N/A	N/A	N/A		
Flowrate		N/A	N/A	N/A		
Pressure Gage	S/N 248	ORIG GAGE	N/A	CONSOLE READING		
3.0 psi	± .15 psi	REPLACED		3.0		
3.5 psi	± .15 psi			3.5		
4.0 psi	± .15 psi			4.0		
4.5 psi	± .15 psi			4.5		
5.0 psi	± .15 psi			5.0		
6.0 psi	± .15 psi			6.0		
~~3.75~~ 4.0 psi	± .15 psi			4.03		
3.5 psi				3.53		
Leakage						
~~0.2~~ 18 psi	180 scc	19 scc/m	N/A	60 sccm; 60 sccm FINAL		
3.75 psi	180 scc	100 scc/m	048 scc/m	~~8~~ 10 sccm PRELIM.		
Pressure Drop		SUIT S(2B) NOT AVAIL			12.0 CFM	
ΔP (in H_2O)					.15 psig	11 in. H_2O
Flowrate scfm					3.5 psig	10 in. H_2O
Suit press. psia						

7/14/69
DATE

CSD MISSION MANAGER

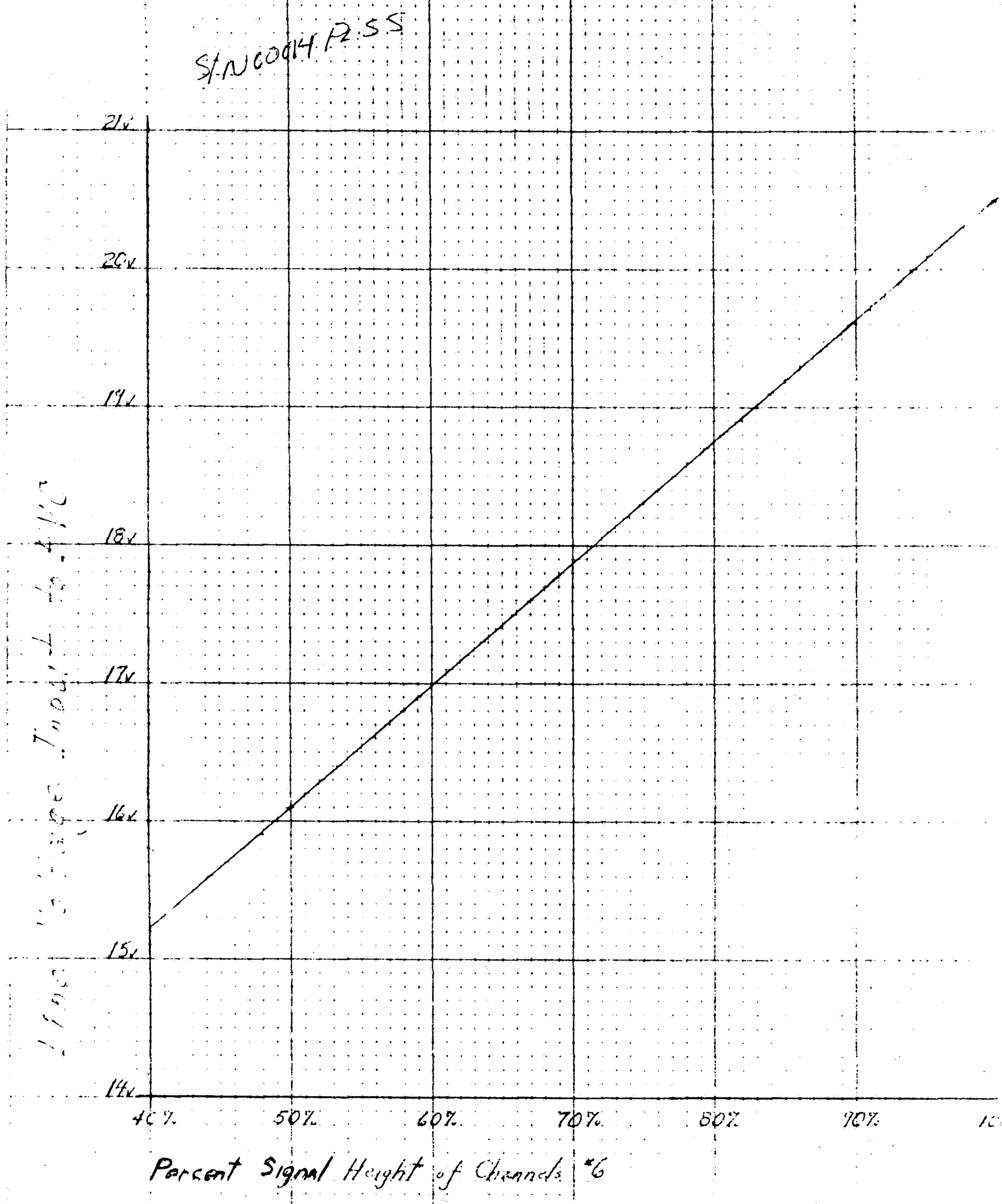
Channel	Actual Reading	Correspondence Value	Telemetry	Date
3	4.00 PSID	60 ± 4	59.5	5/4/69
3	3.00 PSID	20 ± 4	18.3	3/4/69
4	100 mmHg	38.5 ± 3	38.3	5/4/69
4	200 mmHg	77 ± 3	77.2	5/4/69
5	1.05 amp	10.5 ± .5	10.3	5/3/69
5	.65 amp	6.5 ± .5	6.0	5/3/69
6	16	48 ± 3.18	48.0	5/4/69
6	18	70.7 ± 3.18	70.5	5/4/69
7	950	86.5 ± 2.5	86.3	5/4/69
7	590	54 ± 2.5	55.5	5/4/69
7	150	13.5 ± 2.5	15.4	5/4/69
8	Hot Hand Test Yes - Passed			5/4/69
9	77° F	86 ± 4.4	88	5/4/69
10	77° F	86 ± 4.4	87.7	5/4/69

Warning Indicator	
HiO_2 Flow	Act 0.61 pph Deact. - .60
Low Vent Flow	Act. 4.62 acfm Deact. - 4.77
PGA Pressure	Act. 3.20 psid Deact. - 3.35 psid
Feedwater	Act. 1.47 psia Deact. - 1.520 psia

Table G-1 PLSS S/N 00014 Telemetry Readouts and Warning Indicator Actuation Points

22

Figure 7.0-1 Line Voltage Vs Telemetry Signal Amplitude
EVC-2 serial 1161B



9 JAN 1969

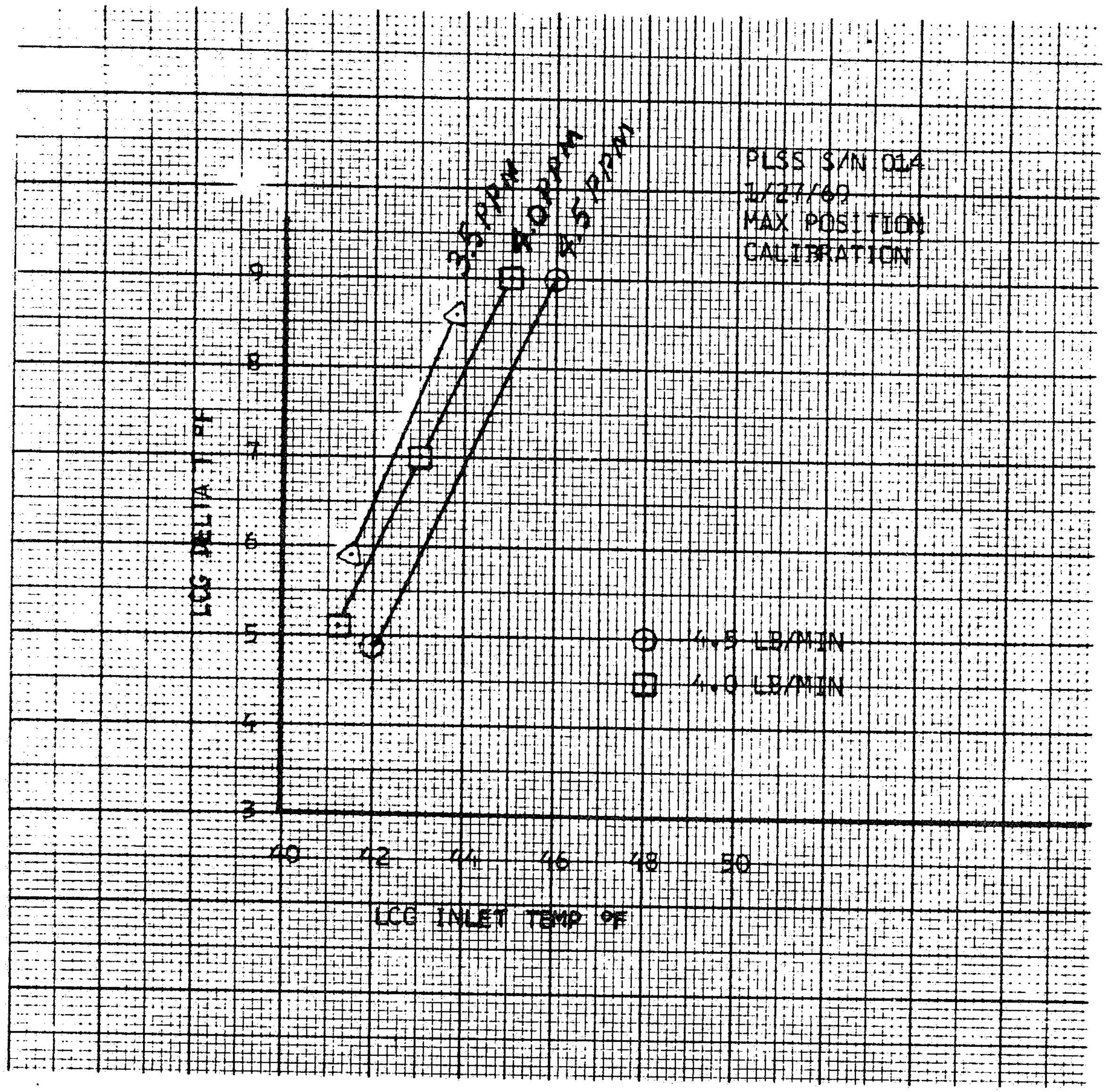


Figure G-2 PLSS S/N 014, SUBLIMATOR CALIBRATION CURVES WITH THE DIVERTER VALVE IN THE 'MAXIMUM' POSITION

PLSS 14

Low Pressure O_2 Loop Leakage	4.0 scc/min	
POS Leakage	.405 psi/hr	
Regulator Internal Leakage	0	
OPS Backflow Check Valve Leakage	.06 lb/hr	
Feedwater Loop External Leakage	.018 $\frac{\text{inches } H_2O}{\text{minute}}$	
Feedwater to O_2 Loop Leakage	0	
Feedwater and Transport Loop Leakage	1.07 cc/hr	
Transport Loop Leakage	.107 cc/hr	
Water Shutoff and Relief Valve	Relief Reseat	56.0 psig 54.0 psig
Feedwater Quantity		8.5 lb.
High O_2 Flow Sensor	Actuation Deactuation	.54 lb/hr .54 lb/hr
Low Vent Flow Sensor	Actuation Deactuation	4.78 acfm 5.00 acfm
Low PGA Pressure Switch	Actuation Deactuation	3.17 psid 3.30 psid
Low Feedwater Pressure Switch	Actuation Deactuation	1.40 psia 1.52 psia

O_2 Regulator Performance

Bottle Pressure (Psig)	Flow (lb/hr)	Regulated Pressure (Psid)
86	.07	3.84
86	.36	3.80
89	.07	3.86
235	.07	3.90
230	.70	3.79
235	.07	3.85
1105	.07	3.90
1104	2.00	3.72
1105	.07	3.85

Pump Performance - see Curve

Fan Performance - see curve

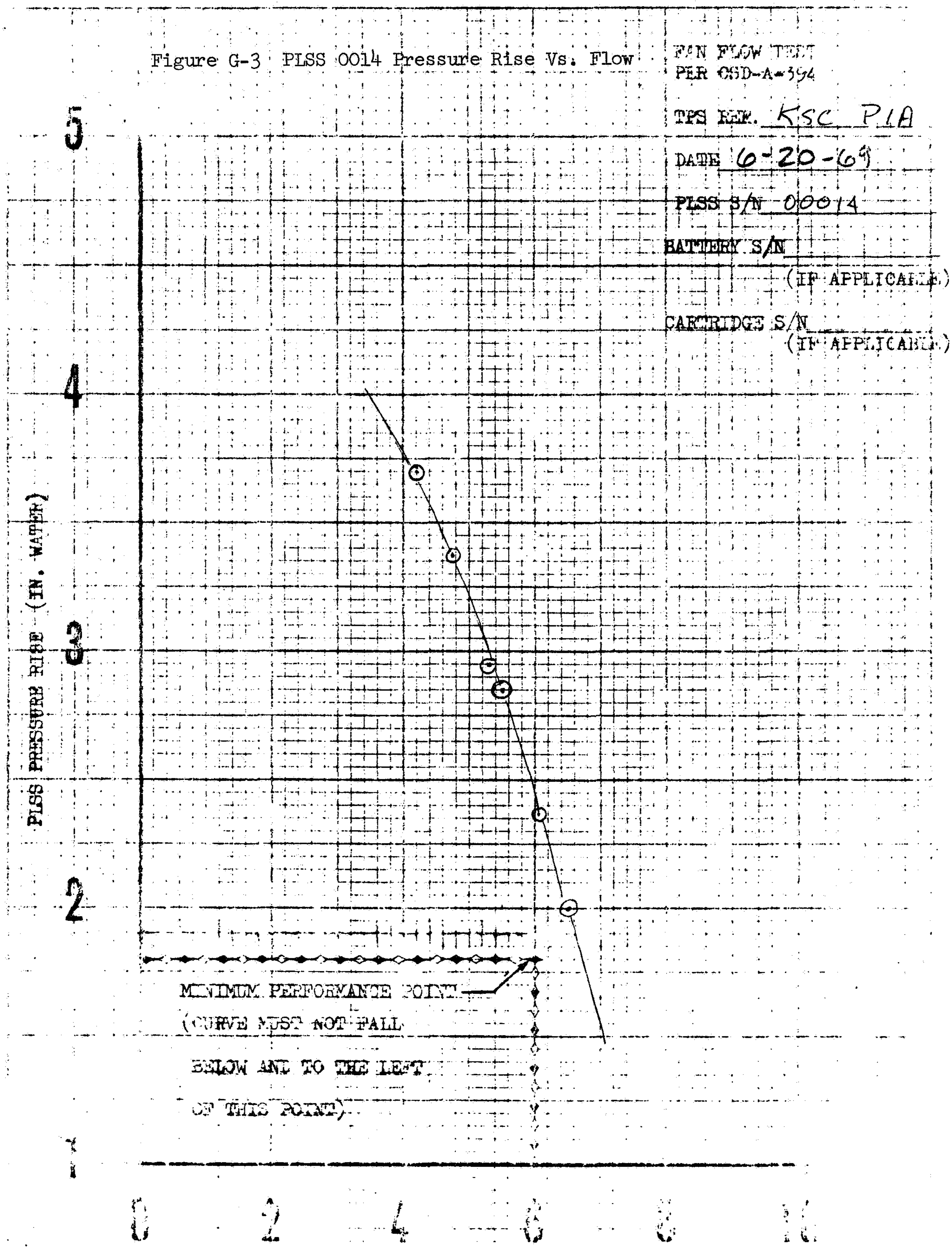
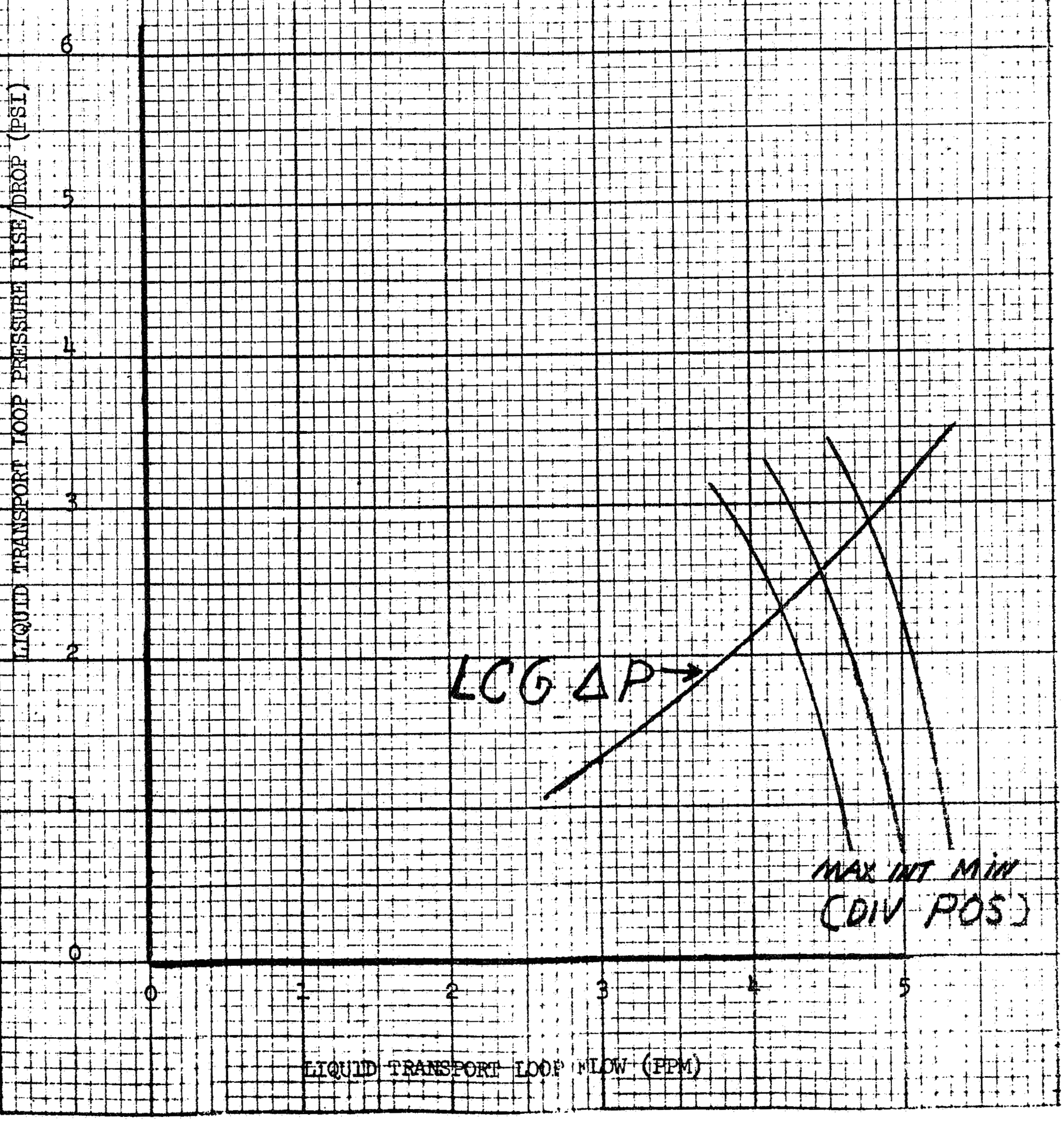


Figure G-3 PLSS 0014 Pressure Rise Vs. Flow
FAN FLOW TEST
PER CSD-A-394
TPS REF. KSC P1A
DATE 6-20-69
PLSS S/N 00014
BATTERY S/N
(IF APPLICABLE)
CARTRIDGE S/N
(IF APPLICABLE)
PLSS PRESSURE RISE (IN. WATER)
5
4
3
2
1
MINIMUM PERFORMANCE POINT
(CURVE MUST NOT FALL
BELOW AND TO THE LEFT
OF THIS POINT)
0
2
4
6
8
10

APOLLO EMU
LIQUID TRANSPORT LOOP
SYSTEM PERFORMANCE
PLSS
S/N 00014
Date 6/22/69
LCG
S/N 079
Date 7/12/69
CREWMAN ALDRIN

Figure G-4 PLSS 0014 Liquid Transport Loop Pressure Rise Vs. Flow



OPS PREFLIGHT PIA DATA

KEY PERFORMANCE CHARACTERISTICS

OPS S/N 0008

1. Checkout gage accuracy -

Actual Δ P	Indicated Δ P
3.43	3.5
3.75	3.8

2. Low pressure external leakage indicated leakage - 1.386×10^{-4} cc/sec at 4.25 psid.

3. High pressure external leakage indicated leakage - 0.14×10^{-4} cc/sec at 6750 psid.

4. Internal leakage (across regulator) indicated leakage - zero

5. Purge flow performance

   Thirty minute flow at 8 lb/hr.
   Bottle pressure decayed from approximately 6400 psig to 1700 psig.
   Regulated Δ P varied from a maximum of 3.68 psid to a minimum of 3.43 psid.

6. Make-up flow performance -

   With bottle pressure of 5750 psig and flow of 0.08 lb/hr., the regulated Δ P range between 3.63 psid and 3.775 psid.

APOLLO 11

FLIGHT PGA CHECKOUT DATA

ALDRIN
CREWMAN

077
PGA S/N

ITEM	SPEC. REQUIREMENT	FACTORY PDA	CAT PIA	FLIGHT PIA	FLIGHT DAY	REMARKS
Relief Valve	S/N 2108					
Crack	5.5 psi	4.9 PSI		4.80 PSI	5.1 psi	
Reseat	4.8 psi	4.8 PSI		4.81 PSI	4.69 psi	
Flowrate @ 5.5 psig		2.0 scf/m		1.9 scf/m	3.0 CFM	
Pressure Gage	S/N 247			CONSOLE READING		
3.0 psi	± .15 psi	PRESSURE GAGE CHANGED		3.02		
3.5 psi	± .15 psi			3.56		
4.0 psi	± .15 psi			4.0		
4.5 psi	± .15 psi			4.5		
5.0 psi	± .15 psi			5.0		
6.0 psi	± .15 psi			6.0		
3.75 psi	± .15 psi					
Leakage						
4.2 IN H_2O ~~0.2 psi~~	180 scc	8 scc/m		8 scc/m		
3.75 psi	180 scc	60 scc/m	31 scc/m	9.5 scc/m		
Pressure Drop		NOT PERFORMED WAIVER # 0321		NOT DONE	12.0 CFM	
ΔP (in H_2O)					.15 psig	11.5 in. H_2O
Flowrate scfm					3.5 psig	9.5 in. H_2O
Suit press. psia					6.0 CFM	
					3.7 psig	3.3 in. H_2O

MISSION MANAGER

7/14/69
DATE

APOLLO 11

FLIGHT LCG CHECKOUT DATA

ALDRIN
CREWMAN

029
LCG S/N

...M	SPEC. REQUIREMENT	FACTORY PDA	CAT PIA	FLIGHT PIA	FLIGHT DAY	REMARKS
...eight	gms			4.02 lb.		
...eight	gms			5 lb 2 oz		
...c Pressure	psig					
...e Date/Time				22:20 7/12/69		
...ure drop		psid				
...lowrate indicated	3.0 ± .1 lb/min	______		1.3 psid		
	3.5 ± .1 lb/min	______		1.7 psid		
	3.8 ± .1 lb/min	______		2.0 psid		
	4.0 ± .1 lb/min	______		2.1 psid		
	4.3 ± .1 lb/min	______		2.4 psid		
	4.5 ± .1 lb/min	______		2.6 psid		
	5.0 ± .1 lb/min	______		3.1 psid		

7/14/69
DATE

Purge Valve 157

Flow Rate = 8.2 lbs/hr. O_2 at $90^{\circ}F$

Leakage Rate = 0 scc/minute at 3.75 $\pm$ .25 psig

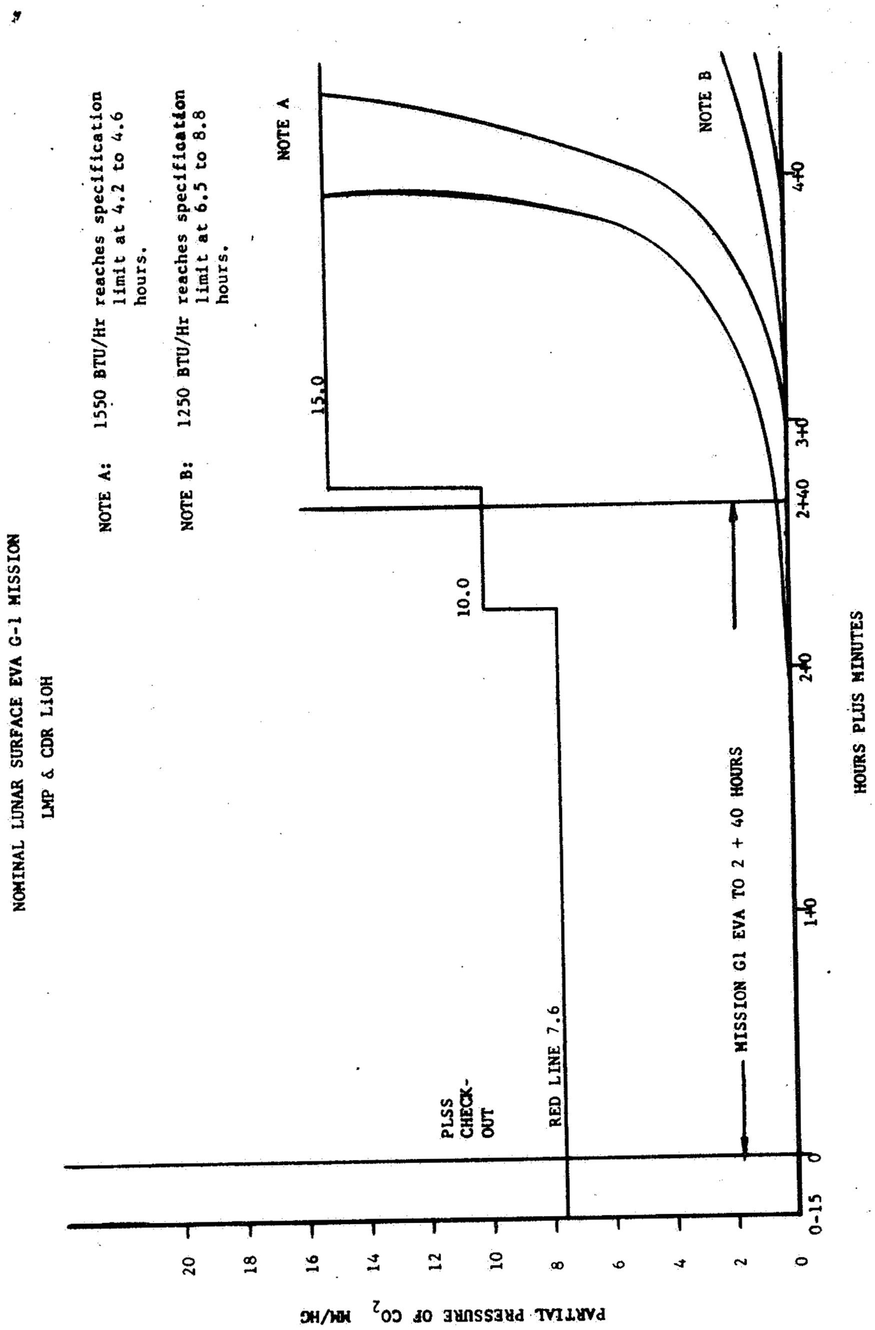


Figure G-5 LMP and CDR CO_2 Buildup (LiOH Depletion)

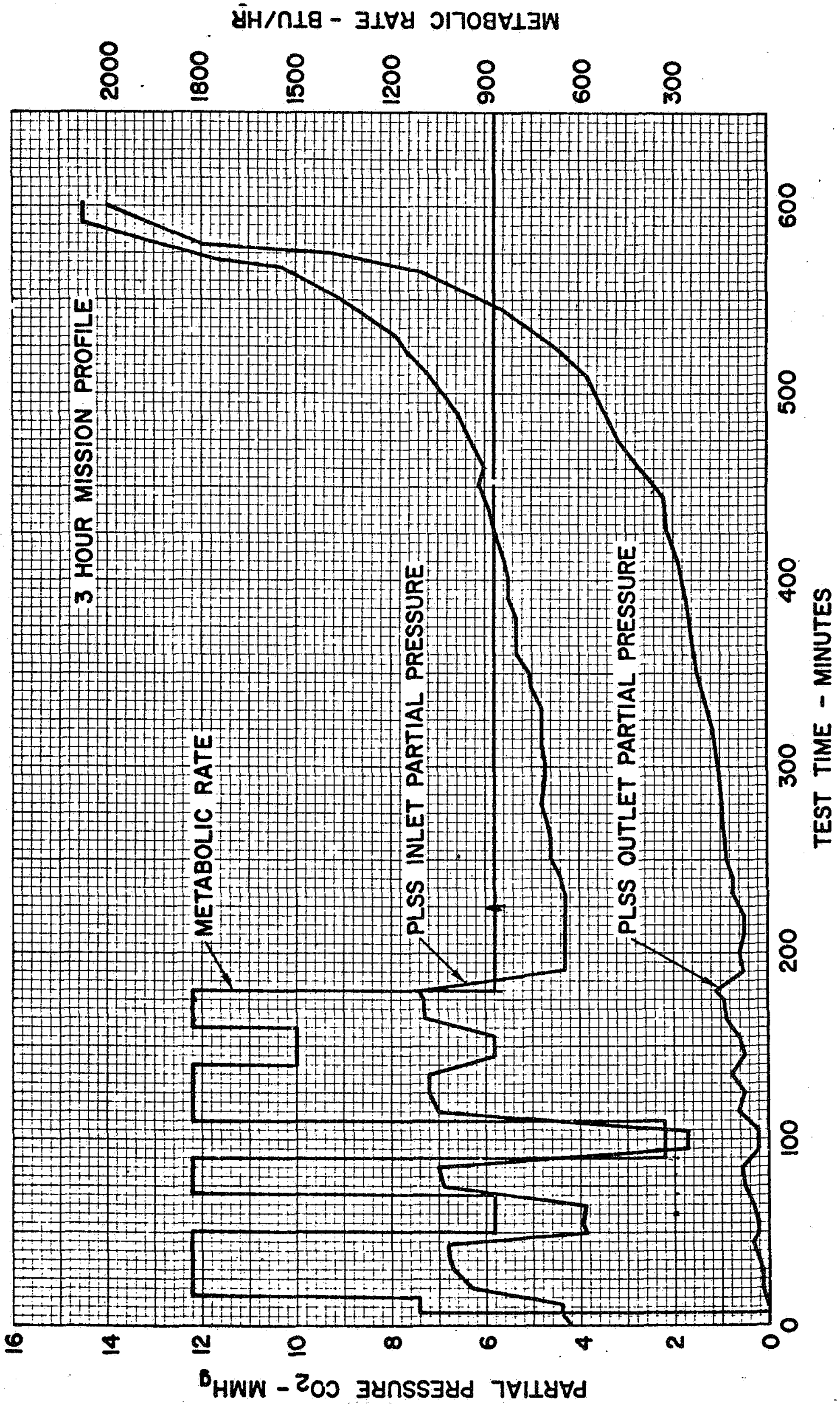


Figure G-6 PLSS CO_2 Partial Pressure Versus Time

JULY 14, 1969

APOLLO 11 CRITICAL DATA SUMMARY SHEET

	PLSS 014	PLSS 015	PLSS 019	OPS 008	OPS 013	OPS 011
Dry Weight* (lbs.)	54.9375	55.1681	62.375	29.6251	29.5625	29.5000
Charged Weight** (lbs.)	79.625	79.625	N/A	40.25	40.0	N/A
O_2 Pressure (psia)	1024.7	1022	1027	5950 @ 74° F	5950 PSI @ 74° F	5960 @ 74° F
Battery Activation Date	7/13/69	7/13/69	N/A	7/10/69	7/11/69	N/A
Lanyard Slide (in.)	N/A	N/A	N/A	.6175	.618	.606
Switch Overtravel (in.)	N/A	N/A	N/A	.010	.012	.017
F/W Quantity (lbs.)	8.5625	8.6251	8.5625	N/A	N/A	N/A
T/W Quantity (lbs.)	1.4375	1.2500	1.3125	N/A	N/A	N/A
LiOH Weight (lbs.)	4.6000	4.6875	N/A	N/A	N/A	N/A
RCU Weight (lbs.)	5.125	5.188	N/A	N/A	N/A	N/A
Battery Shelf Life	Sept. 1968	Sept 1968	N/A	Jan. 1969	Jan. 1969	N/A
RCU Serial No.	008	010	N/A	N/A	N/A	N/A
Battery Serial No.	S-147	S-139	N/A	S-47	S-46	N/A
LiOH Cartridge Serial Number	136	138	N/A	N/A	N/A	N/A

* Less RCU, Thermal Cover, Harness, Battery and Cartridge
** Completely Flight Configured, Less RCU

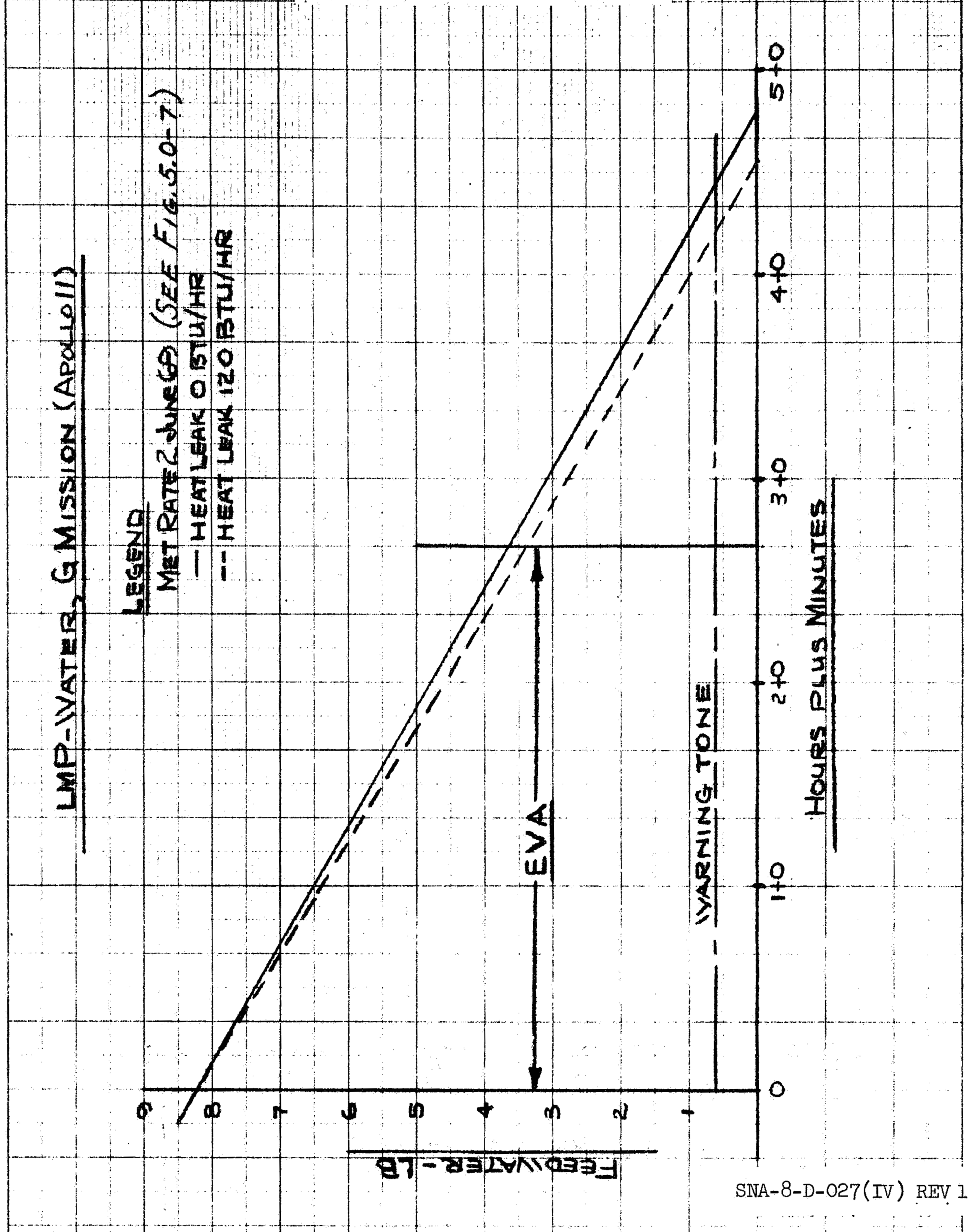
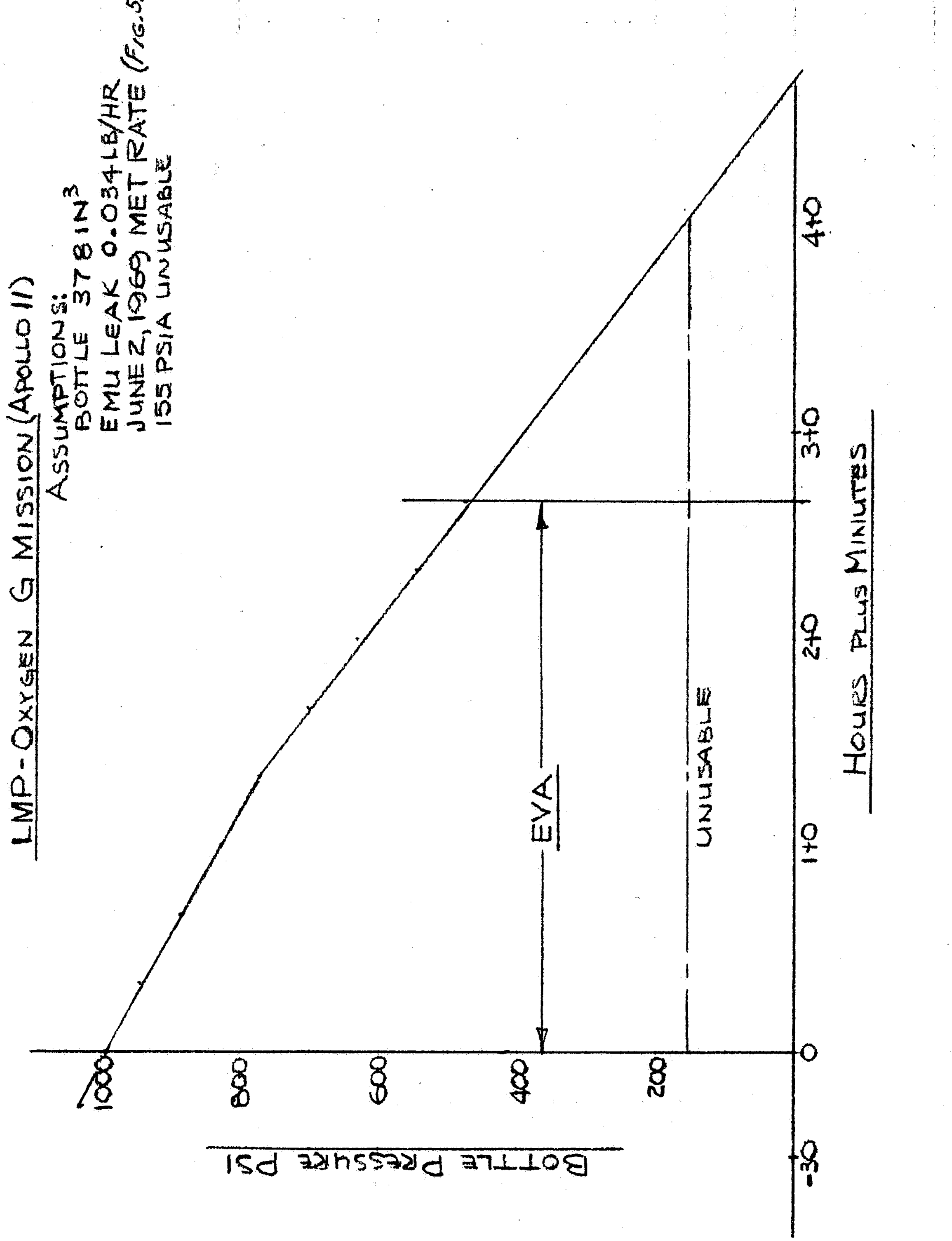


Figure G-7 LMP Feedwater Depletion Rate



SNA-8-D-027 (IV) REV 1

Figure G-8 LMP Oxygen Depletion Rate

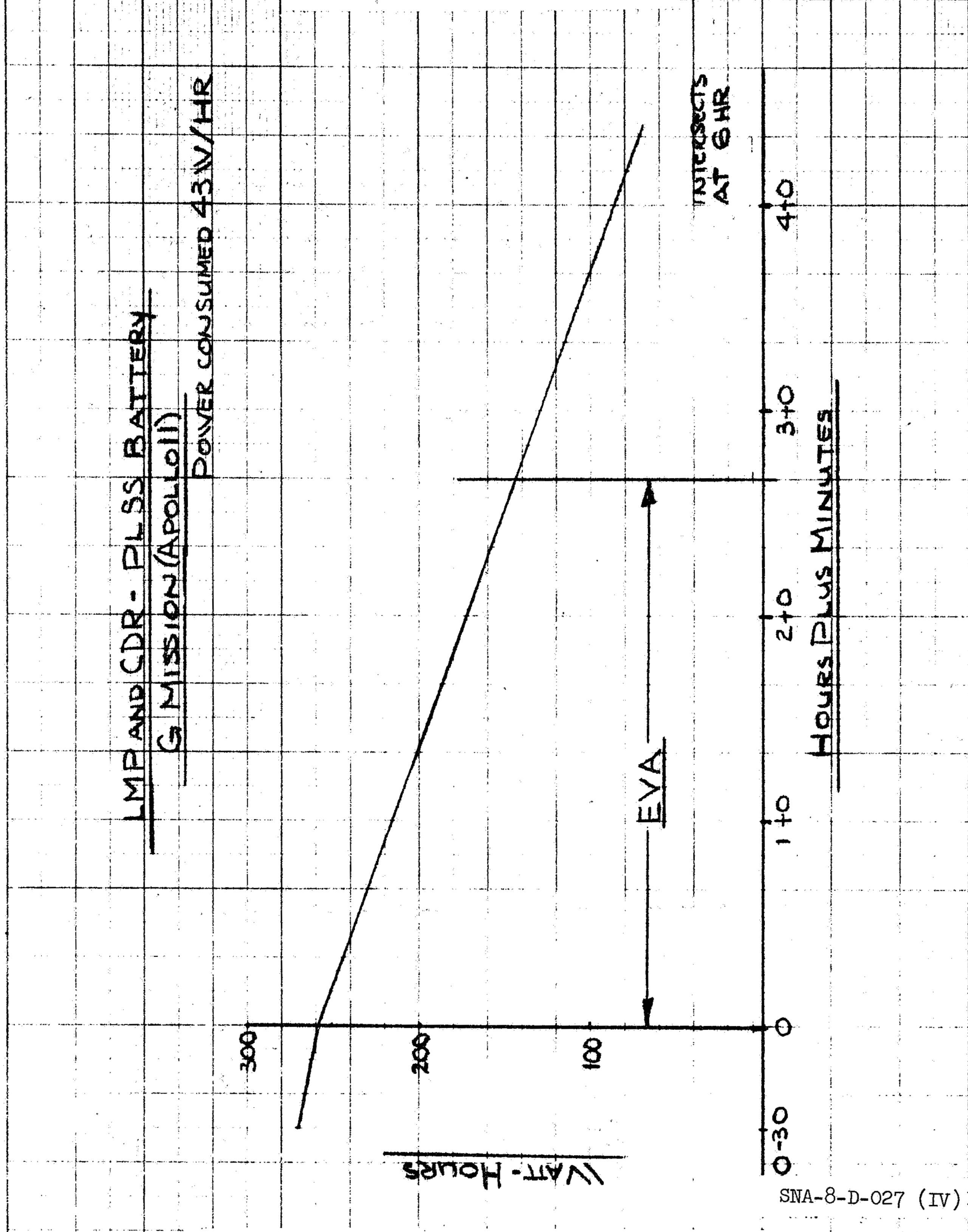


Figure G-9 LMP and CDR PLSS Battery Depletion Rate

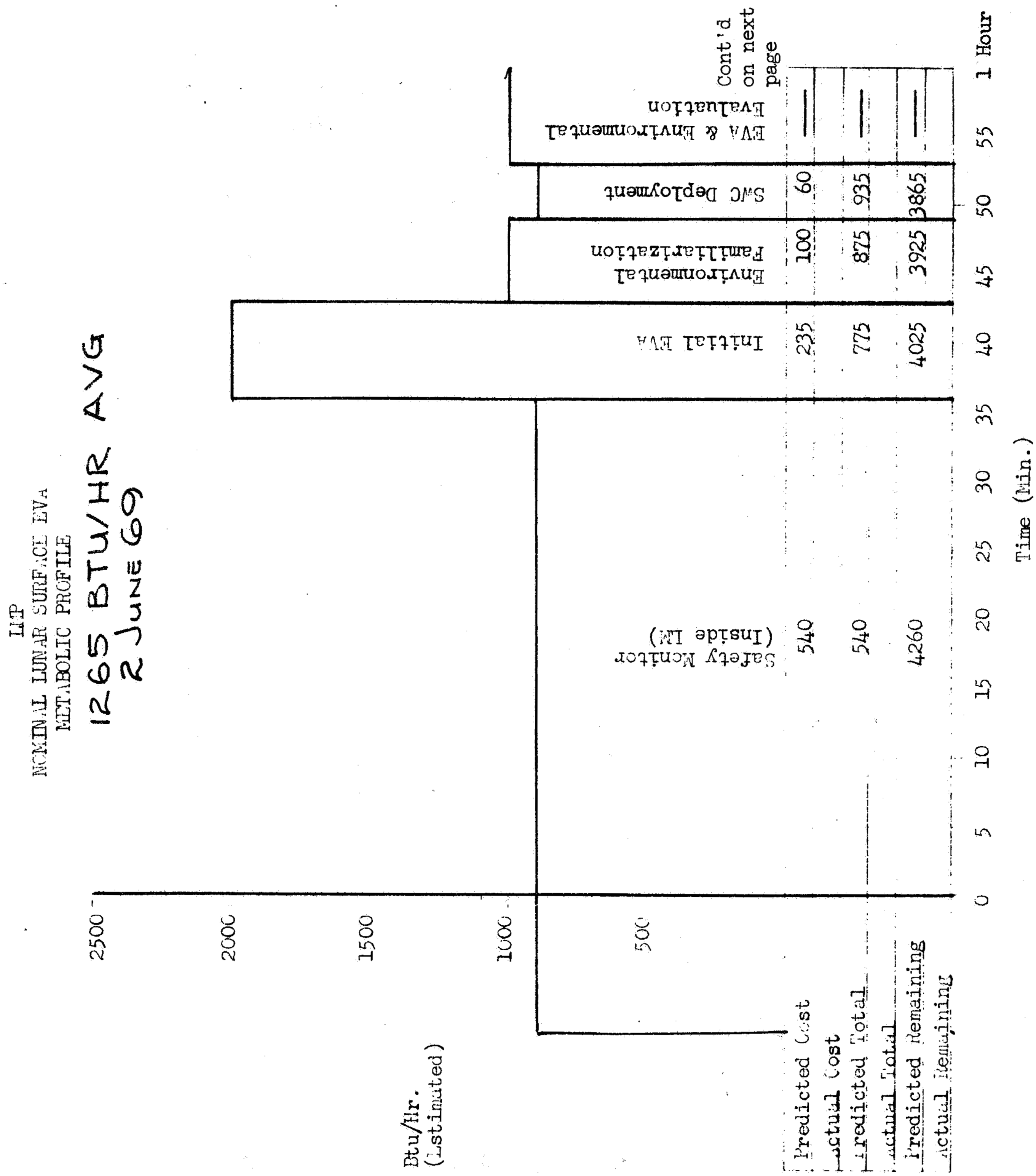


Figure G-10 LMP Nominal Lunar Surface EVA Metabolic Profile

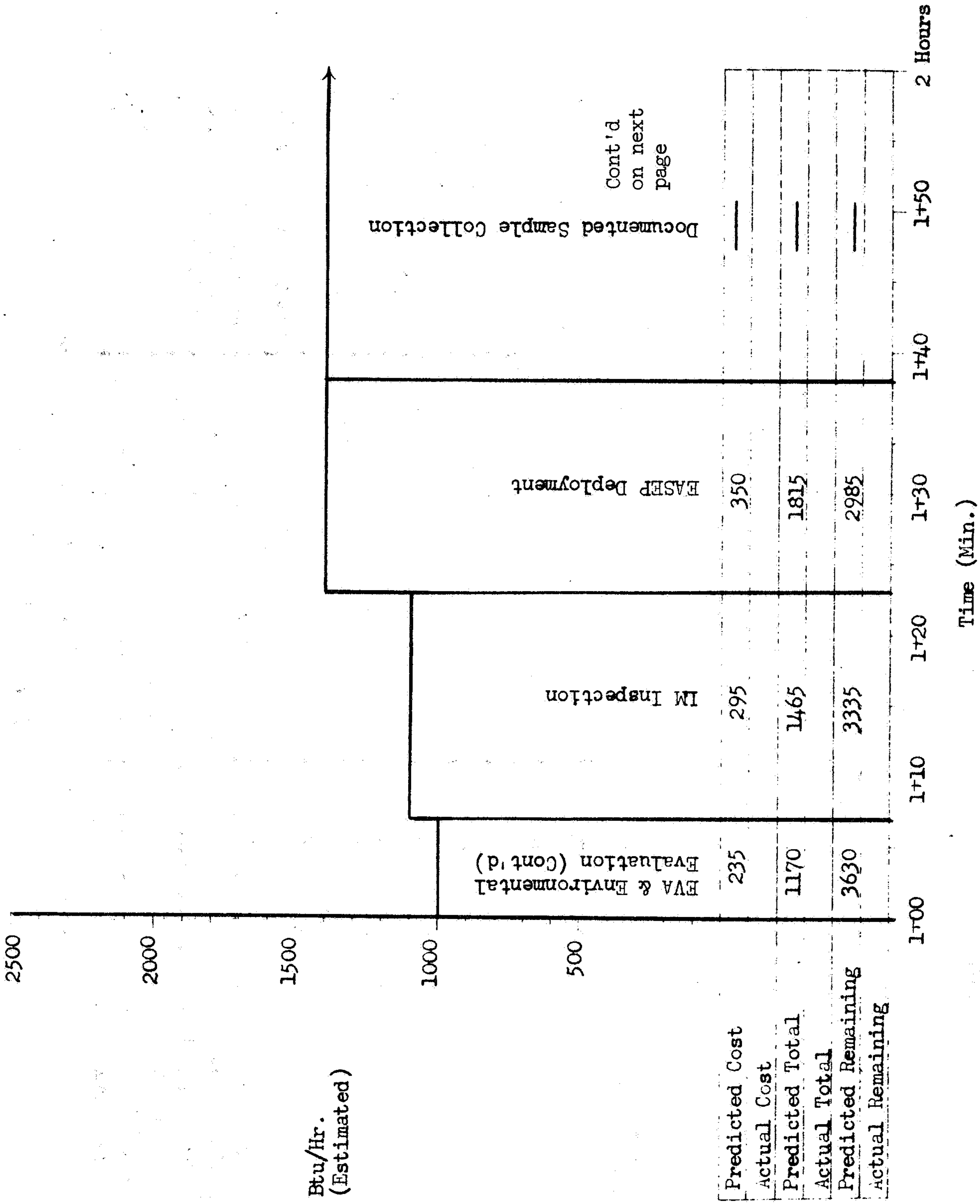


Figure G-11 LMP Nominal Lunar Surface EVA Metabolic Profile (Cont'd)

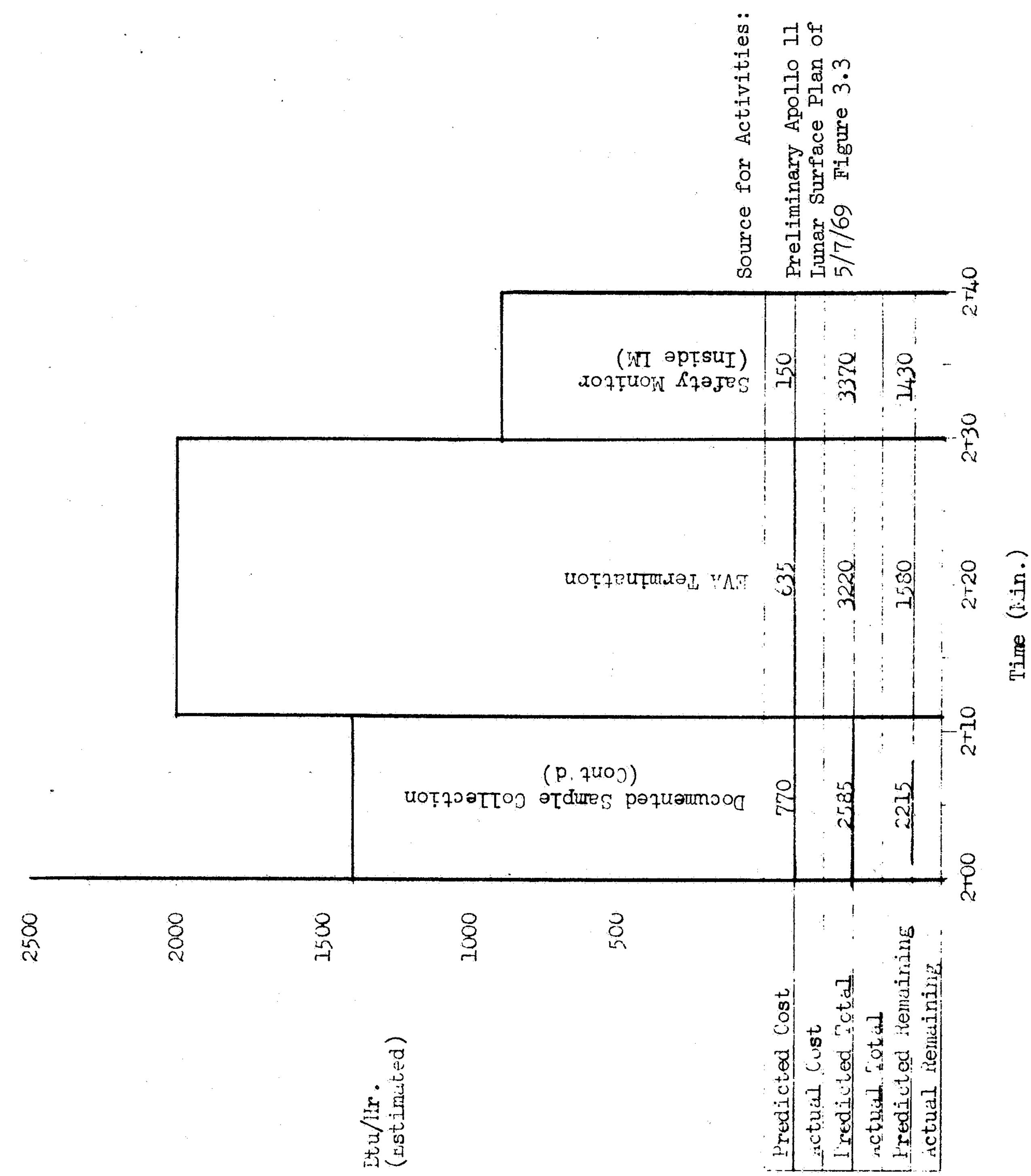


Figure G-12 LMP Nominal Lunar Surface EVA Metabolic Profile (Cont'd)

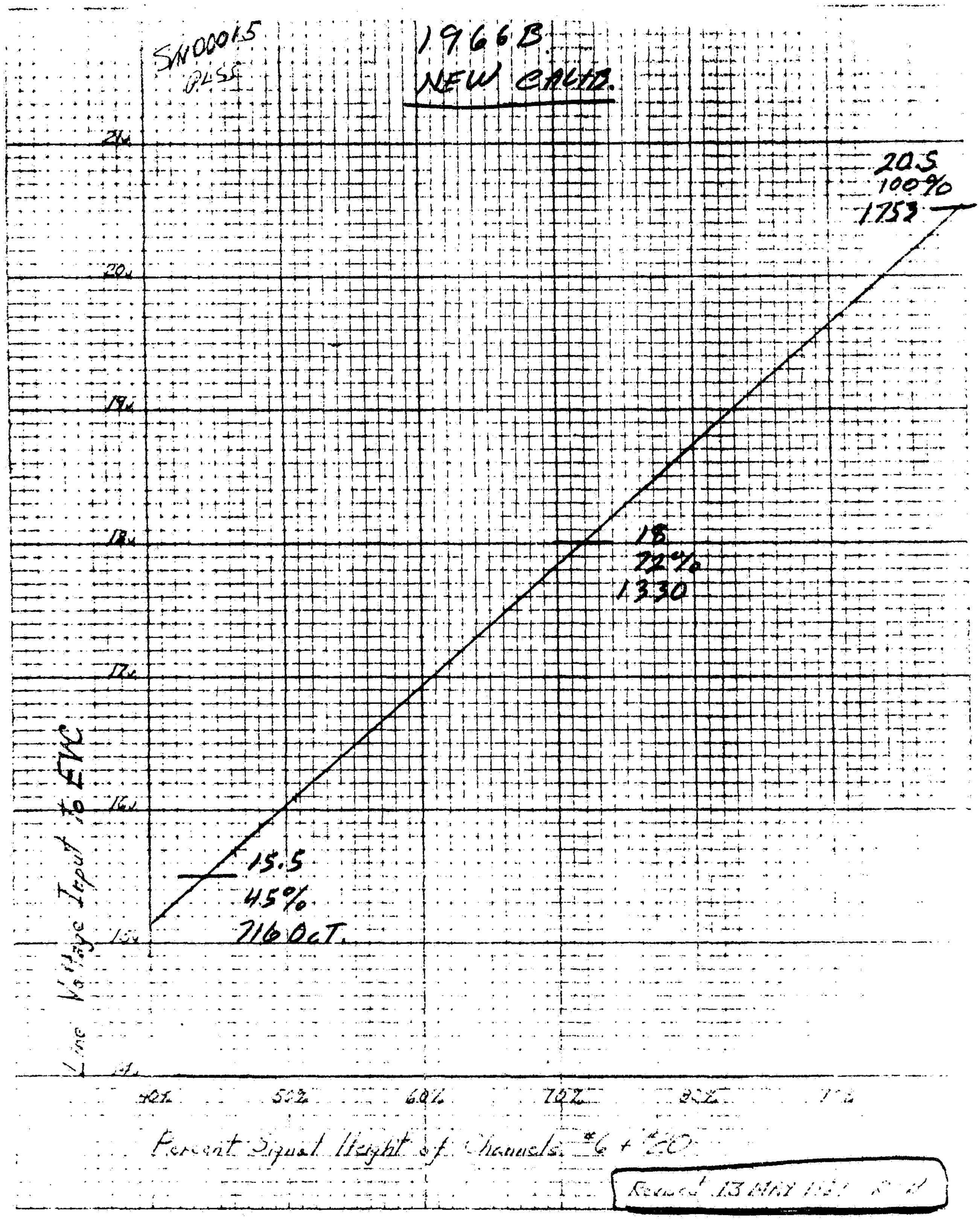
Channel	Actual Reading	Correspondence Value	Telemetry	Date
3	4.0 psid	60% ± 4	58.8	4/30/69
3	3.0 psid	20 ± 4	18.1	4/30/69
4	101 mmHg	39 ± 3	38.4	4/30/69
4	200 mmHg	77 ± 3	76.75	4/30/69
5	1.1 amp	11 ± .5%	10.1	4/30/69
5	.58 amp	5.8 ± .5%	5.8	4/30/69
6	16 volts	48 ± 3.18	48.8	4/30/69
6	18 volts	71 ± 3.18	70.90	4/30/69
7	950 psig	87 ± 2.8	85.7	4/30/69
7	600 psig	55 ± 2.8	57.4	4/30/69
7	150 psig	14 ± 2.5	16.0	4/30/69
8	Hot Hand Test - Passed			4/30/69
9	77.2° F	86 ± 4.4%	87.7	4/30/69
10	77.2° F	86 ± 4.4%	85.7	4/30/69

Warning Indicators		
Hi O_2 Flow	Act. 0.59 pph Deact.- 0.56 pph	4/30/69
Low Vent Flow	Act. 4.79 acfm Deact.- 4.88 acfm	4/30/69
PGA Pressure	Act. 3.29 psid Deact.- 3.34 psid	4/30/69
Feedwater	Act. 1.33 psia Deact.- 1.46 psia	4/30/69

Table G-2 PLSS S/N 00015 Telemetry Readouts and Warning Indicator Actuation Points

Figure G-13 Line Voltage Vs. Telemetry Amplitude

EVC-1 Serial 1966B



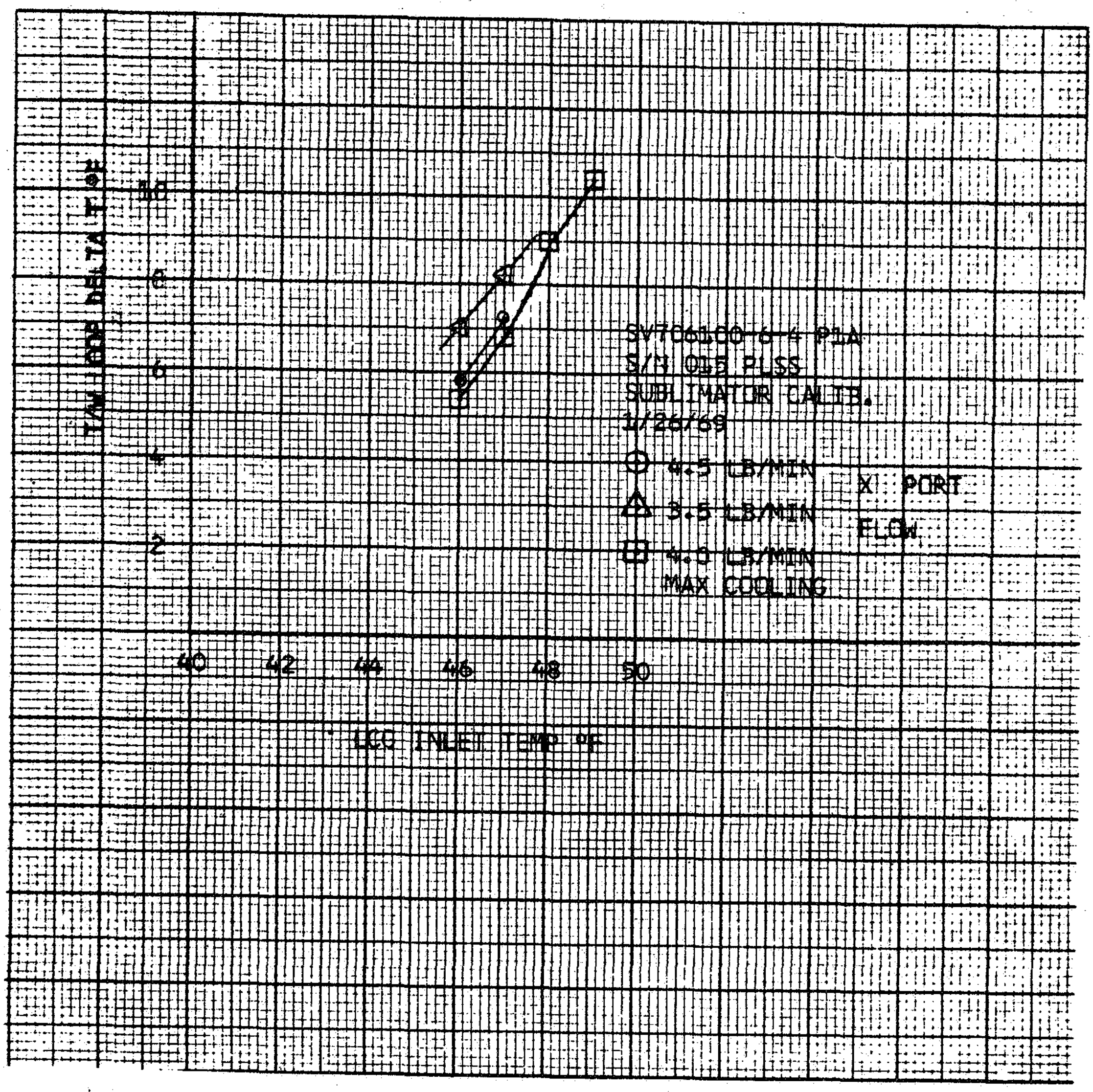


Figure G-14 PLSS S/N 015, SUBLIMATOR CALIBRATION CURVES WITH THE DIVERTER VALVE IN THE 'MAXIMUM' POSITION

28

PLSS 15

Low Pressure O_2 Loop Leakage	4.5 $\frac{scc}{min}$
POS Leakage * Actual reading - pressure increase of .05 $\frac{psi}{hr}$ MRB buy-off	0
Regulator Internal Leakage	0
OPS Back Flow Check Valve Leakage	.06 $\frac{lb}{hr}$
Feedwater Loop External Leakage	.004 $\frac{\text{inches } H_2O}{\text{minute}}$
Feedwater to O_2 Loop Leakage	0
Feedwater and Transport Loop Leakage	1.61 $\frac{cc}{hr}$
Transport Loop Leakage	.21 $\frac{cc}{hr}$
Water Shutoff and Relief	Relief 57 psig Reseat 54 psig
Feedwater Quantity	8.5 lb.
High O_2 Flow Sensor	Actuation .495 $\frac{lb}{hr}$ Deactuation .48 $\frac{lb}{hr}$
Low Vent Flow Sensor	Actuation 4.68 acfm Deactuation 4.92 acfm
Low PGA Pressure Switch	Actuation 3.20 psid Deactuation 3.27 psid
Low Feedwater Pressure Switch	Actuation 1.38 psia Deactuation 1.52 psia

O_2 Regulation Performance

Bottle Pressure (psig)	Flow (lb/hr)	Regulated Pressure (psid)
85	.07	3.90
88	.36	3.87
90	.07	3.92
238	.07	3.96
235	.70	3.88
235	.07	3.93
1105	.07	3.99
1102	1.97	3.83
1110	.07	3.97

Pump Performance - See curve

Fan Performance - See curve

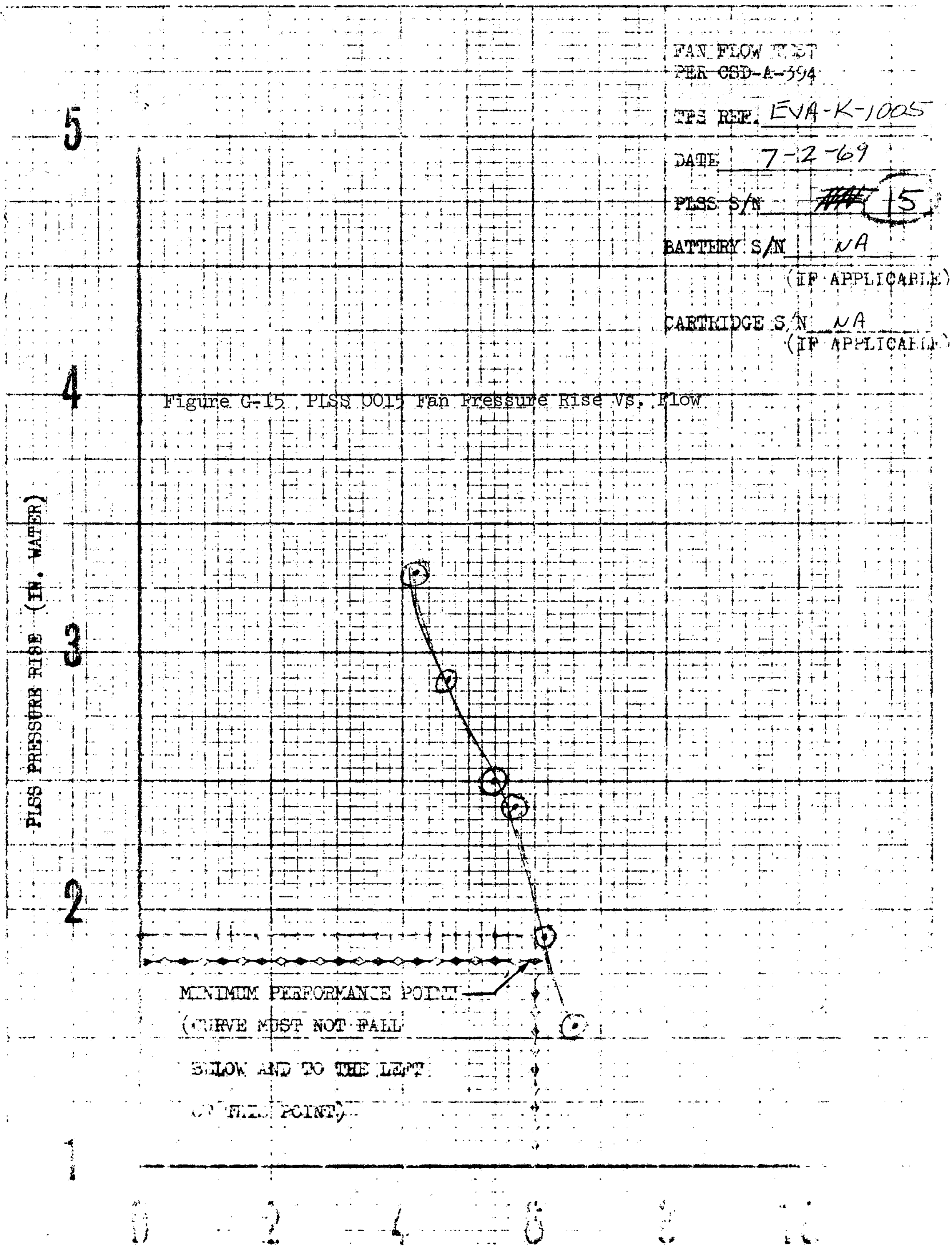
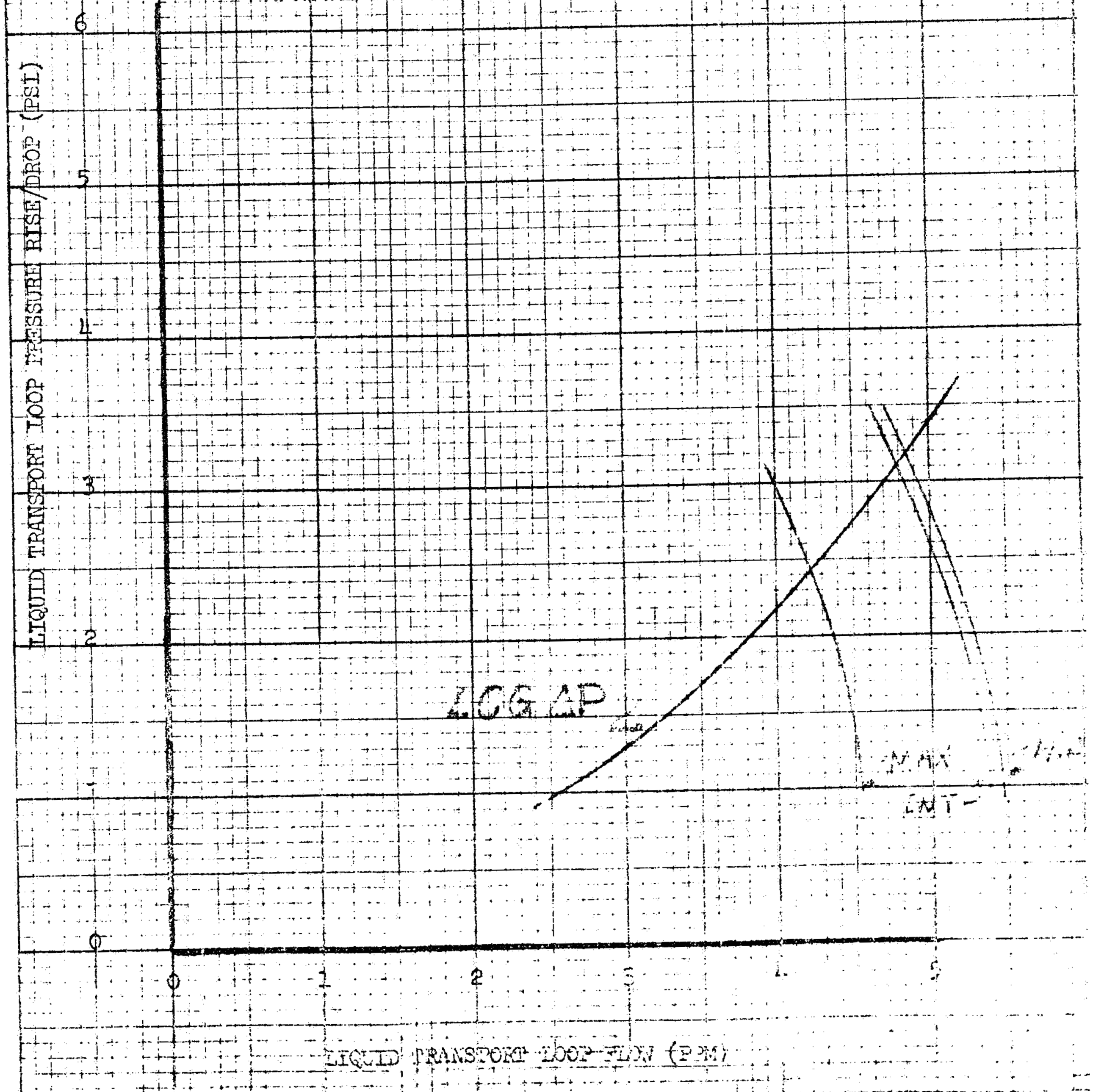


Figure G-15 PLSS 0015 Fan Pressure Rise Vs. Flow

APOLLO EMU
LIQUID TRANSPORT LOOP
SYSTEM PERFORMANCE
PLSS
S/N 0015
Date [illegible]
LCG
S/N [illegible]
Date [illegible]
CREWMAN [illegible]

Figure G-16 PLSS 0015 Liquid Transport Loop Pressure Rise Vs. Flow



OPS PREFLIGHT PIA DATA

KEY PERFORMANCE CHARACTERISTICS

OPS S/N 00013

1. Checkout gage accuracy -

Actual P	Indicated P
3.5 psi	3.45 psi
3.8 psi	3.75 psi

2. Low pressure external leakage indicated leakage - zero cc/sec at 4.25 psi P.

3. High pressure external leakage indicated leakage - 1.03 x 10^{-4} cc/sec at 6750 psi P.

4. Internal leakage (across regulator) indicated leakage - 24 cc/min.

5. Purge flow performance -

   Thirty minute flow at 8 lb/hr
   Bottle pressure decayed from approximately 6000 psig to 1200 psig
   Regulated P varied from a maximum of 3.655 psid to minimum of 3.45 psid.

6. Makeup flow performance -

   With bottle pressure of 6750 psig and flow of 0.08 lb/hr., the regulated P ranged between 3.785 psid and 3.8 psid.

APOLLO

FLIGHT PGA CHECKOUT DATA

ARMSTRONG
CREWMAN

056
PGA S/N

ITEM	SPEC. REQUIREMENT	FACTORY PDA	CAT PIA	FLIGHT PIA	FLIGHT DAY	REMARKS
Relief Valve	S/N ~~2155~~ 2123	PRV REPLACED	PRV REPLACED			
Crack	5.5 psi	~~4.8~~		4.90	4.85 [redacted] psi	
Reseat	4.8 psi	~~[illegible]~~		4.75	4.65 [redacted] psi	
Flowrate @ 5.5 psig				[redacted]	3.0 CFM	
Pressure Gage @	S/N 249	ORIG GAGE REPLACED	ORIG GAGE/ REPLACED	CONSOLE READING		
3.0 psi	± .15 psi			3.10		
3.5 psi	± .15 psi			3.58		
4.0 psi	± .15 psi			4.08		
4.5 psi	± .15 psi			4.60		
5.0 psi	± .15 psi			5.10		
6.0 psi	± .15 psi			6.10		
5 ~~3.45~~ psi 4.0	± .15 psi			3.60 4.10		
Leakage						
~~8.0~~ 0.18 psi	180 scc	38 scc/m	N/A	5 scc/m		
3.75 psi	180 scc	80 scc/m	45 scc/m	33 scc/m		IV GLOVES
3.75 psi				50 scc/m		EV GLOVES
Pressure Drop		SUIT SUBJECT NOT AVAIL @ PDA	NOT PERFORMED	NOT PERFORMED		
ΔP (in H_2O)					12.0 CFM .15 psig	10.5 in. H_2O
Flowrate scfm					3.5 psig	8.6 in. H_2O
Suit press. psia					6.0 CFM 3.9 psig	3.4 in. H_2O

[illegible signature]
[illegible] MANAGER

7/14/69
DATE

Volume IV EMU Data Book
PGA and Accessories Characteristics-Mission G-1
APOLLO 11

FLIGHT LCG CHECKOUT DATA

ARMSTRONG
CREWMAN

077
LCG S/N

ITEM	SPEC. REQUIREMENT	FACTORY PDA	CAT PIA	FLIGHT PIA	FLIGHT DAY	REMARKS
Weight	gms			1762 gms		
-eight	gms			4 lb. 14 oz		
-ge Pressure	psig					
-ge Date/Time				3:07 7/14/69		
-ssure drop		psid		PSID		
Flowrate indicated	3.0 ± .1 lb/min	______		1.3	~~[illegible]~~	
	3.5 ± .1 lb/min	______		1.8	~~[illegible]~~	
	3.8 ± .1 lb/min	______		1.95		
	4.0 ± .1 lb/min	______		2.35		
	4.3 ± .1 lb/min	______		2.5		
	4.5 ± .1 lb/min	______		2.6		
	5.0 ± .1 lb/min	______		3.4		

________ MANAGER

7/14/69
DATE

Purge Valve 155

Flow Rate = 8.2 lbs/hr. O_2 at 90°F

Leakage Rate = 0 scc/minute at 3.75 $\pm$ .25 psig.

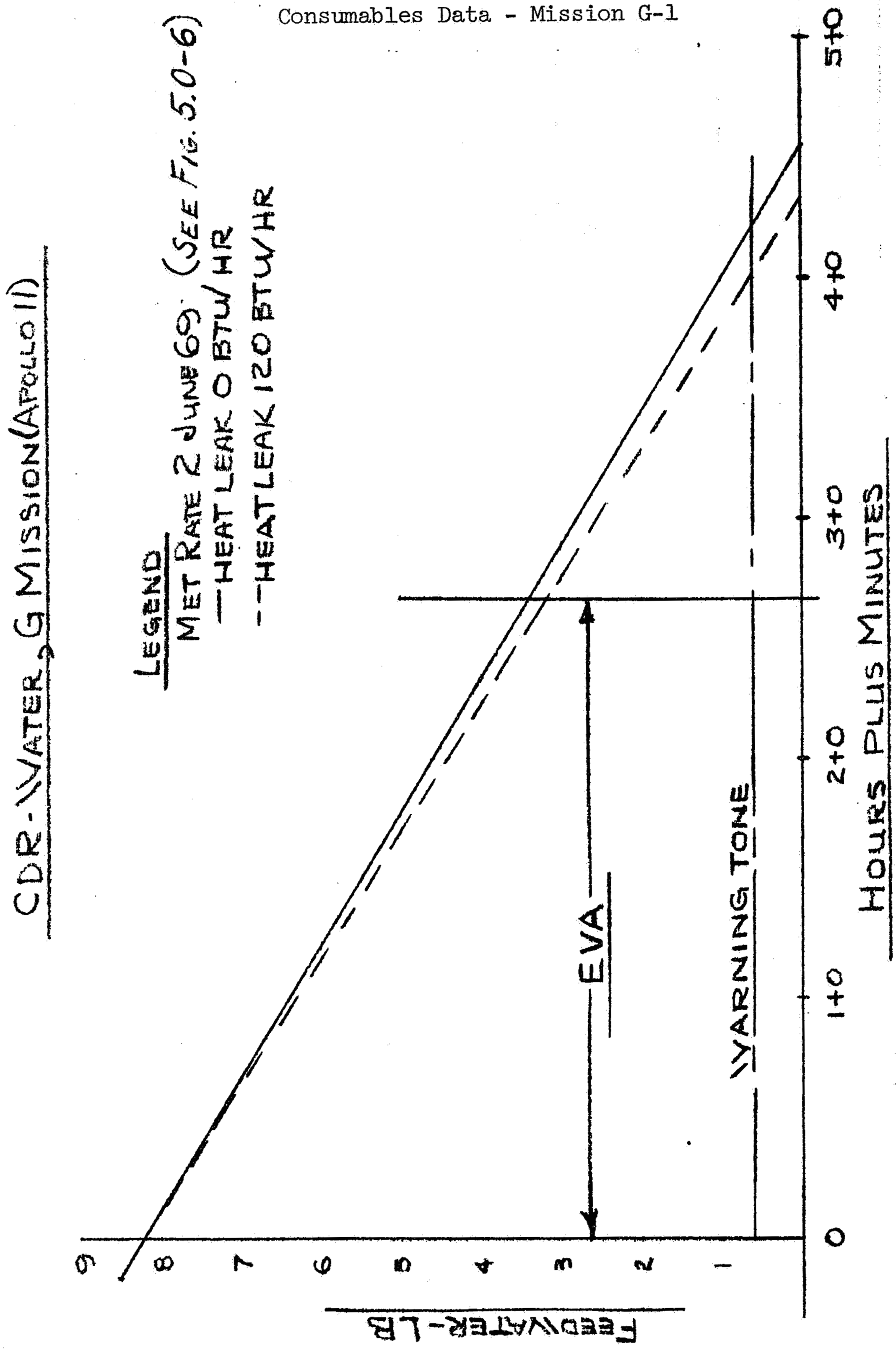


Figure G-17 CDR Feedwater Depletion Rate

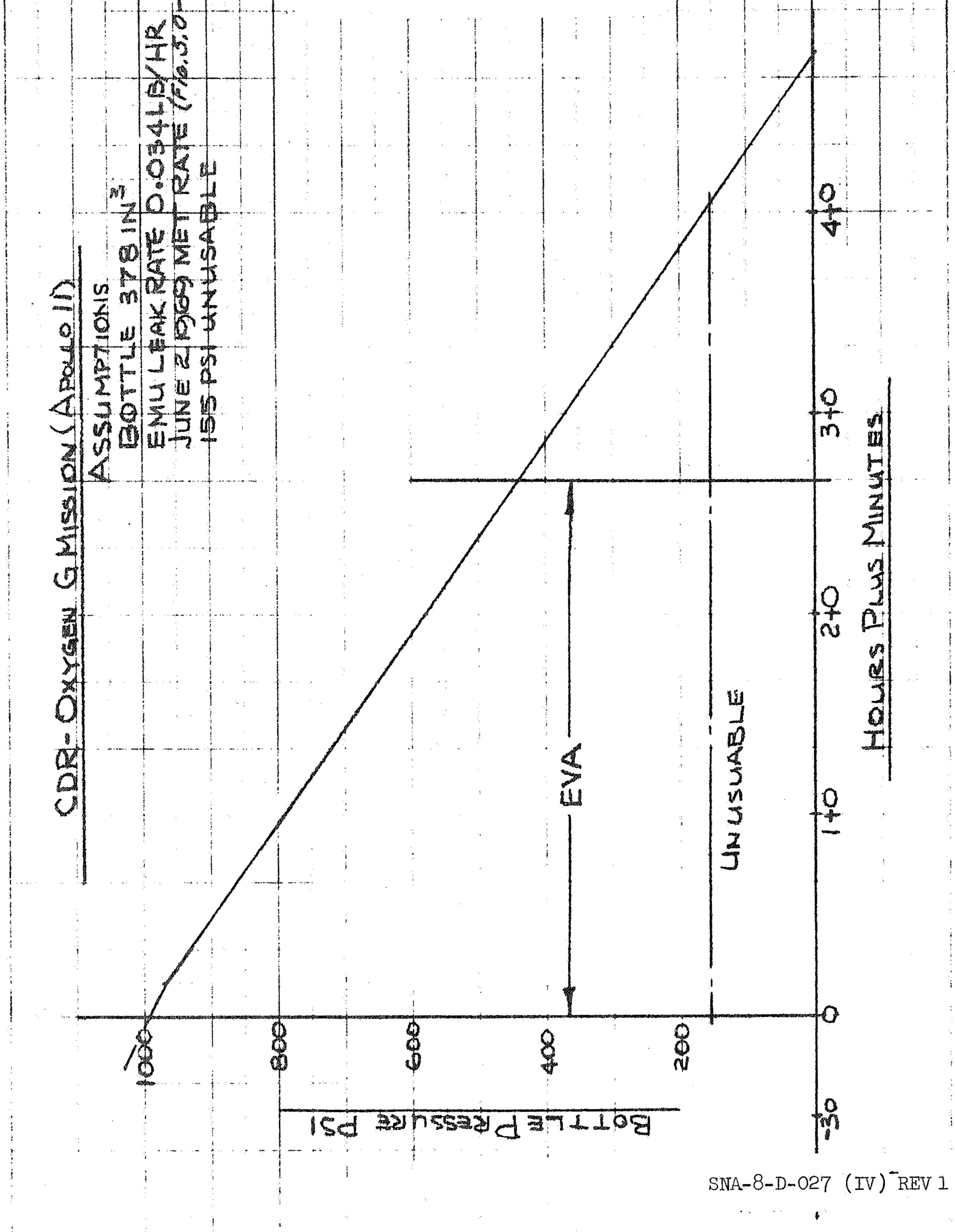


Figure G-18 CDR Oxygen Depletion Rate

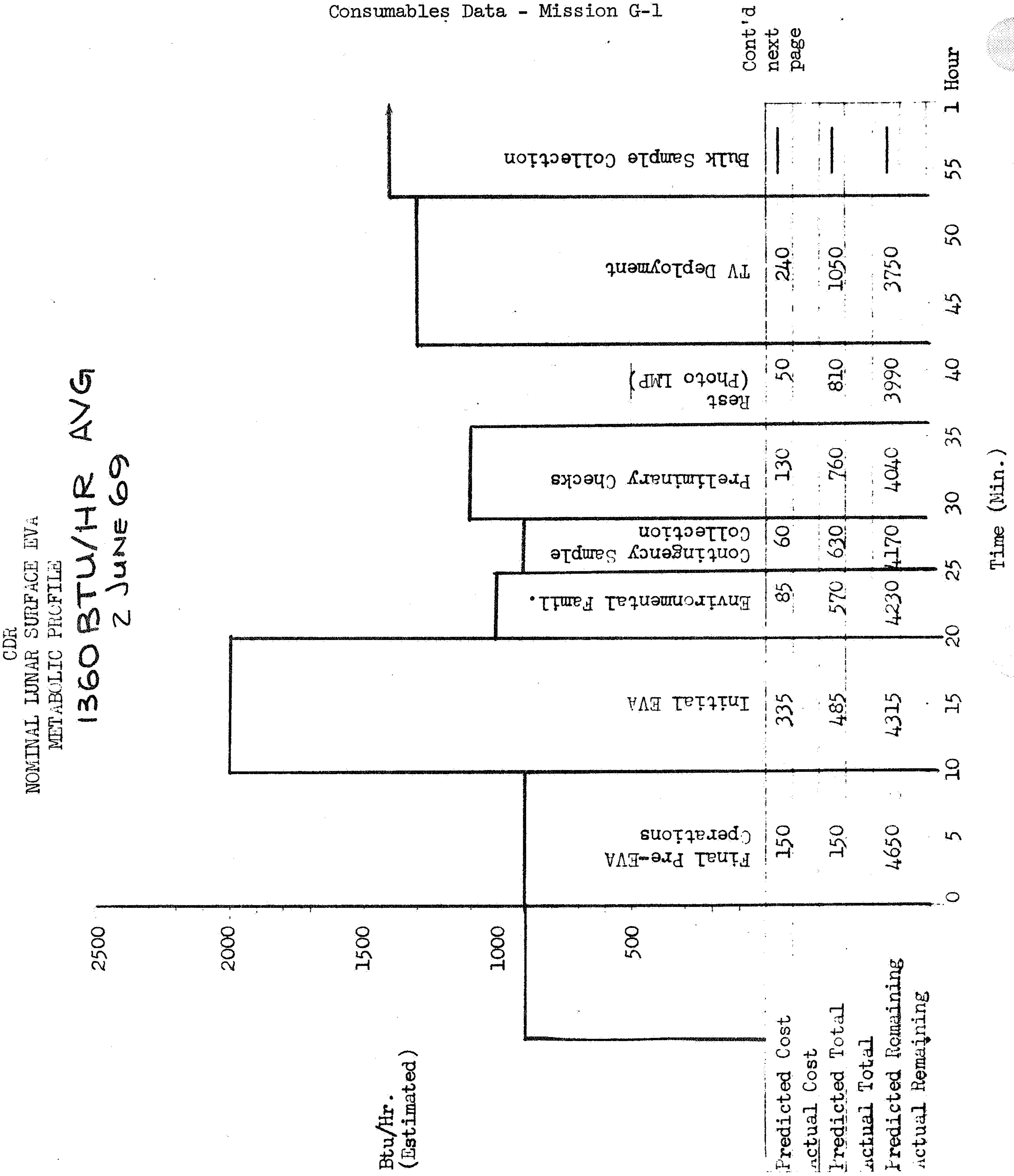


Figure G-19 CDR Nominal Lunar Surface EVA Metabolic Profile

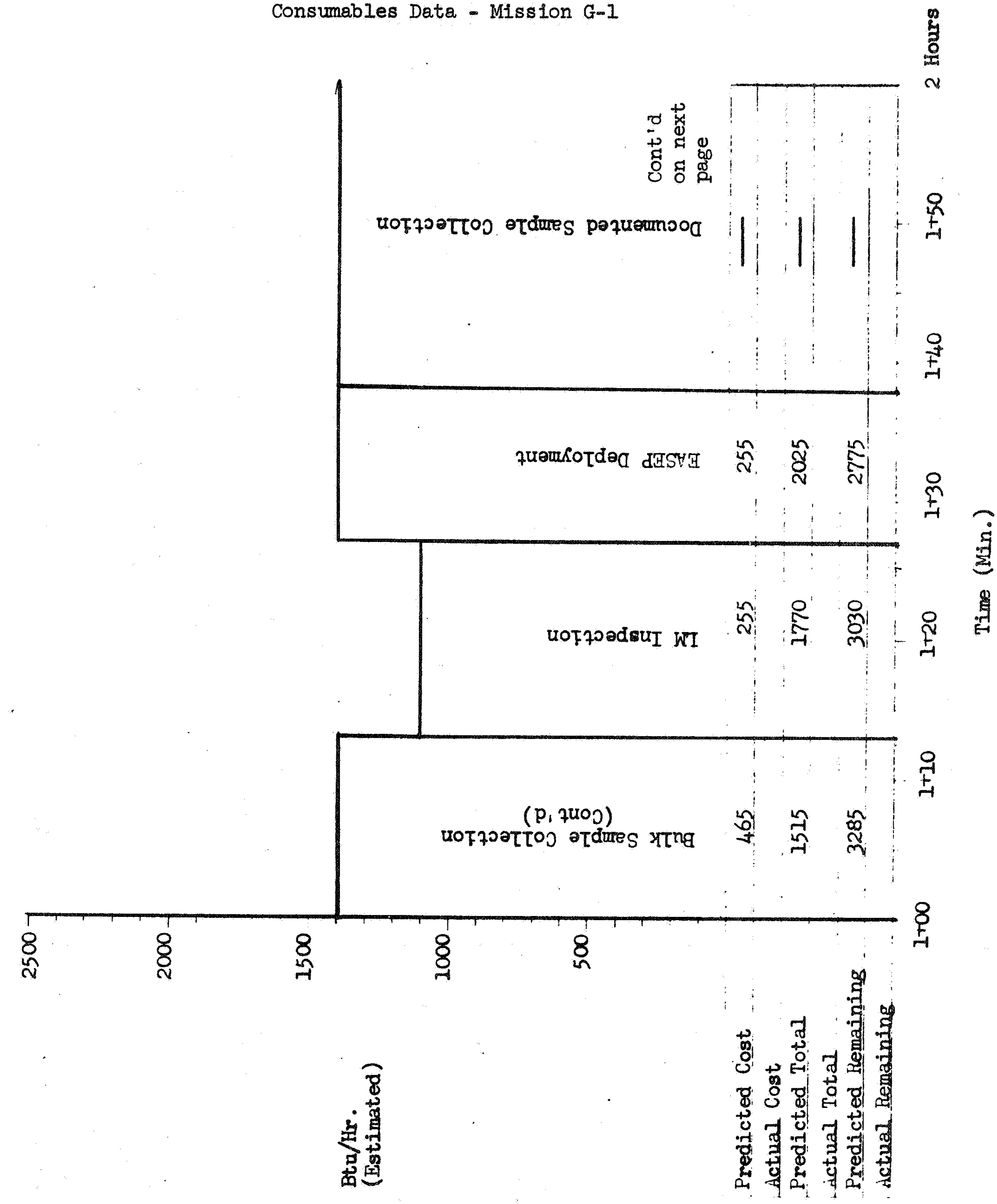


Figure G-20 CDR Nominal Lunar Surface EVA Metabolic Profile (Cont'd)

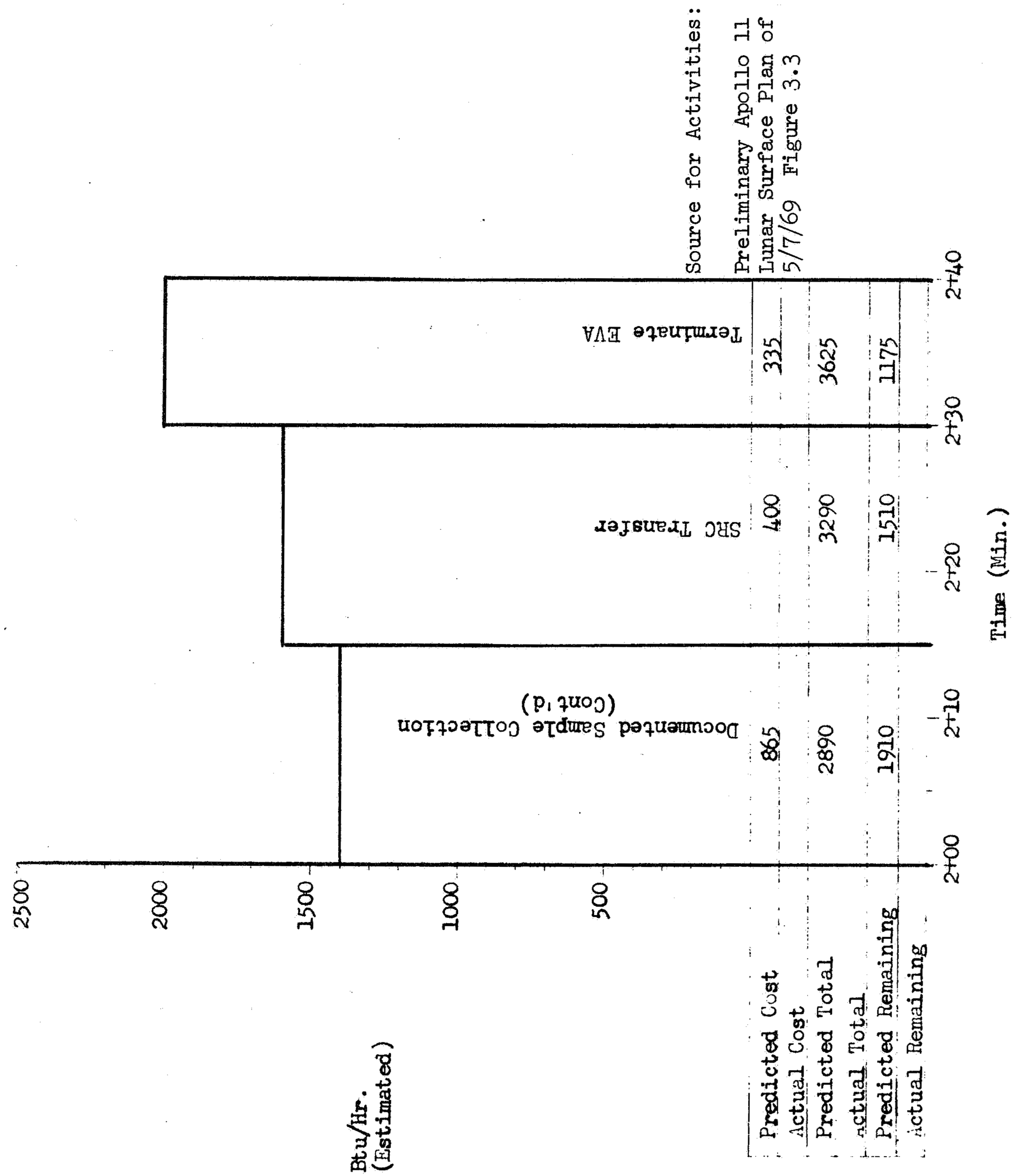


Figure G-21 CDR Nominal Lunar Surface EVA Metabolic Profile (Cont'd)

H MISSION APPENDIX

APOLLO 12

Equipment Assignment Matrix and Appendix Data Location

Crewman / Equipment	CMP		LMP		CDR	
	S/N	Page	S/N	Page	S/N	Page
PLSS*	---	---	018	H-3	019	H-12
OPS*	---	---	018	H-8	011	H-17
PGA	066	H-2	067	H-9	065	H-18
LCG	---	---	093	H-10	091	H-19
EVCS**	---	---	1969B	---	1972B	---
LEVA*	---	---	011	---	012	---
Purge Valve*	---	---	139	H-11	138	H-20
Consumables	---	---	---	H-21	---	H-21

* Interchangeables between crewmen

** Communications data combined with PLSS data

APOLLO 12

FLIGHT PGA CHECKOUT DATA

R. GORDON, CMP
CREWMAN

A7L-066
PGA S/N

ITEM	SPEC. REQUIREMENT	FACTORY PDA	CAT PIA	FLIGHT PIA	FLIGHT DAY	REMARKS
1) Relief Valve	S/N N/A					
Crack	5.5 psi			N/A		
Reseat	4.8 psi			N/A		
Flowrate				N/A		
2) Pressure Gage	S/N 261					
3.0 psi	± .15 psi			3.03		
3.5 psi	± .15 psi			3.49		
4.0 psi	± .15 psi			4.0		
4.5 psi	± .15 psi			4.5		
5.0 psi	± .15 psi			5.0		
~~6.0 psi~~ 5.5 psi	± .15 psi			5.49		
~~3.75 psi~~ 6.0 psi.	± .15 psi			5.99		
3) Leakage						
0.2 psi	180 scc			5		
3.75 psi	180 scc			55		
4) Pressure Drop						
ΔP (in H_2O)				10.0 N/A		
Flowrate scfm				12.0 N/A		
Suit press. psia				8.2 N/A		

IV mode

CSD MISSION MANAGER

DATE

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PLSS

S/N 00018

Low Pressure O_2 Loop Leakage	0 SCC/Min.
POS Leakage	0.49 psi.hr
Regulator Internal Leakage	0 SCC/min.
OPS Back Flow Check Valve Leakage	0.2 pph
Feedwater Loop External Leakage	.0008 in. H_2O/Min.
Feedwater to O_2 Leakage	65 SCC/Min.
Feedwater and Transport Loop Leakage	1.55 cc/hr.
Transport Loop Leakage	0.27 cc/hr
Water Shutoff and Relief	Relief 58 psi Reseat 49.5 psig
Feedwater Quantity	8.475 pounds
High O_2 Flow Sensor	Actuation 0.51 pph Deactuation 0.50 pph
Low Vent Flow Sensor	Actuation 4.01 acfm Deactuation 4.10 acfm
Low PGA Pressure Switch	Actuation 3.25 psid Deactuation 3.35 psid
Low Feedwater Pressure Switch	Actuation 1.43 psid Deactuation 1.51 psia

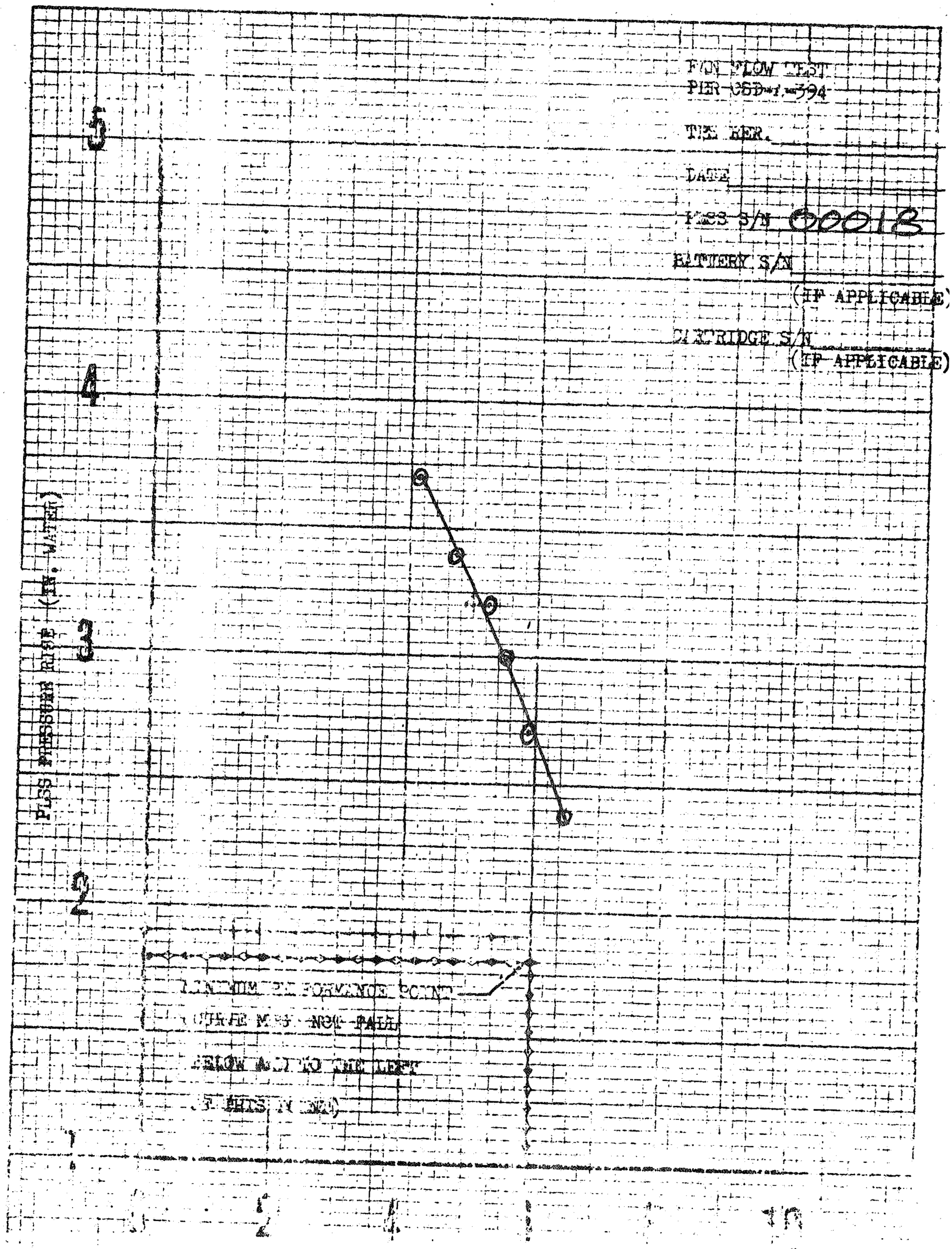
PLSS S/N 018

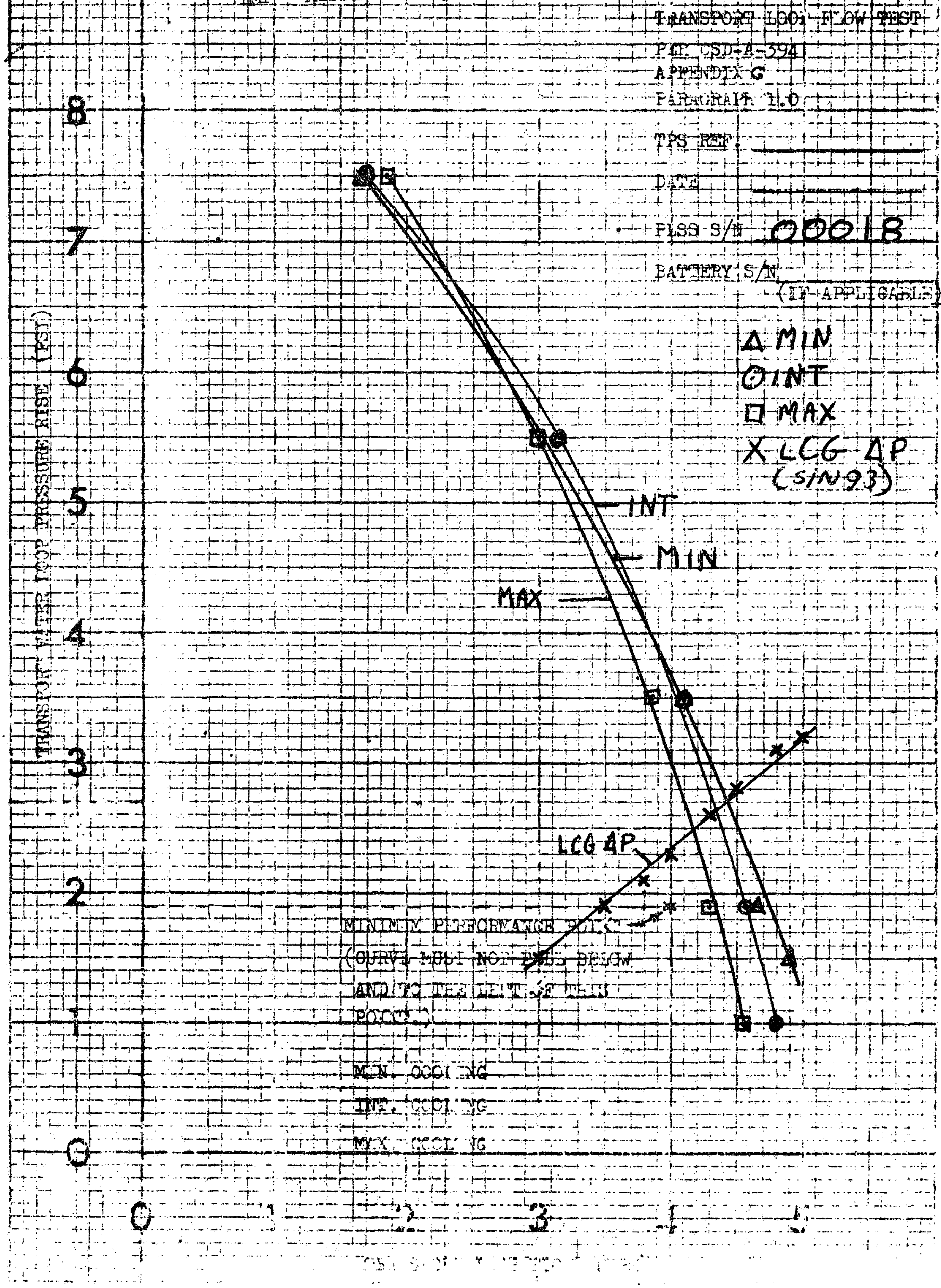
O_2 Regulation Performance

Bottle Pressure (psig)	Flow (lb/hr)	Regulated Pressure (psid)
82	.07	3.87
85	.350	3.85
90	.07	3.90
235	.07	3.9
235	.65	3.82
230	.07	3.90
1100	.07	3.92
1105	2.0	3.78
1110	.07	3.91

Pump Performance - See curve.

Fan Performance - See curve.


FAN FLOW TEST
PER CSD-A-394
TESTER
DATE
PLSS S/N 00018
BATTERY S/N
(IF APPLICABLE)
CARTRIDGE S/N
(IF APPLICABLE)
5
4
3
2
PLSS PRESSURE RISE (IN. WATER)
MINIMUM PERFORMANCE POINT
CURVE MAY NOT FALL
BELOW AND TO THE LEFT
OF THIS POINT


TRANSPORT LOOP FLOW TEST
REF CSD-A-394
APPENDIX G
PARAGRAPH 11.0
TPS REF.
DATE
PLSS S/N 00018
BATTERY S/N
(IF APPLICABLE)
Δ MIN
O INT
□ MAX
X LCG ΔP
(S/N 93)
INT
MIN
MAX
LCG ΔP
MIN. COOLING
INT. COOLING
MAX. COOLING
8
7
6
5
4
3
2
1
0
0
3

OPS PRE FLIGHT PIA DATA

KEY PERFORMANCE CHARACTERISTICS

OPS S/N 018 SV 730101-2-15

1. CHECKOUT GAGE ACCURACY

Actual Delta P	Indicated Delta P
3.5 psid	3.45 psid
3.8 psid	3.73 psid

2. LOW PRESSURE EXTERNAL LEAKAGE

Indicated Leakage 0 cc/sec.

Delta P 4.25 psid

3. HIGH PRESSURE EXTERNAL LEAKAGE

Indicated Leakage 0 cc/sec.

Delta P Full Charge

4. INTERNAL LEAKAGE (ACROSS REGULATOR)

Indicated Leakage 12.5 cc/min.

5. PURGE FLOW PERFORMANCE FOR THIRTY-MINUTE FLOW AT 8.3 LB/HR FLOW RATE

Bottle Pressure - Start 6500 psig

Stop 1400 psig

Regulator Delta P During Run

Maximum 3.68 psid

Minimum 3.53 psid

6. MAKE-UP FLOW PERFORMANCE

Bottle Pressure 6750 psig

Flow Rate 0.08 lb/hr

Regulated Delta P Range 3.73 PSID

Maximum ______ psid

Minimum ______ psid

FLIGHT PGA CHECKOUT DATA

A. BEAN, LMP
CREWMAN

A7L-067
PGA S/N

ITEM	SPEC. REQUIREMENT	FACTORY PDA	CAT PIA	FLIGHT PIA	FLIGHT DAY	REMARKS
1) Relief Valve	S/N 2080					
Crack	5.5 psi			5.05		
Reseat	4.8 psi			5.01		
Flowrate				4.8		
2) Pressure Gage	S/N 143					
3.0 psi	± .15 psi			2.96		
3.5 psi	± .15 psi			3.47		
4.0 psi	± .15 psi			3.98		
4.5 psi	± .15 psi			4.5		
5.0 psi	± .15 psi			5.0		
6.0 psi	± .15 psi			6.00		
3.75 psi	± .15 psi			N/A		
3) Leakage						
0.2 psi	180 scc			13.5		
3.75 psi	180 scc			51		
4) Pressure Drop						
ΔP (in H_2O)				3.3	8.3	
Flowrate scfm				6.0	12.0	
Suit press. psia				18.7	18.2	
				EV mode	IV mode	

CSD MISSION MANAGER

DATE

APOLLO 12

FLIGHT LCG CHECKOUT DATA

A. BEAN
CREWMAN

093
LCG S/N

TEM	SPEC. REQUIREMENT	FACTORY PDA	CAT PIA	FLIGHT PIA	FLIGHT ~~DAY~~ CHARGE	REMARKS
Weight	gms				1651 gms.	
weight	gms				1952 gms	
ge Pressure	psig				13.8 psig	
ge Date/Time					10 Nov 69 1905	
sure drop		psid				
Flowrate indicated	3.0 ± .1 lb/min			1.5		
	3.5 ± .1 lb/min			1.9		
	3.8 ± .1 lb/min			2.1		
	4.0 ± .1 lb/min			2.3		
	4.3 ± .1 lb/min			2.6		
	4.5 ± .1 lb/min			2.8		
	4.8			3.1		
	5.0 ± .1 lb/min			3.2		

ED MISSION MANAGER

DATE

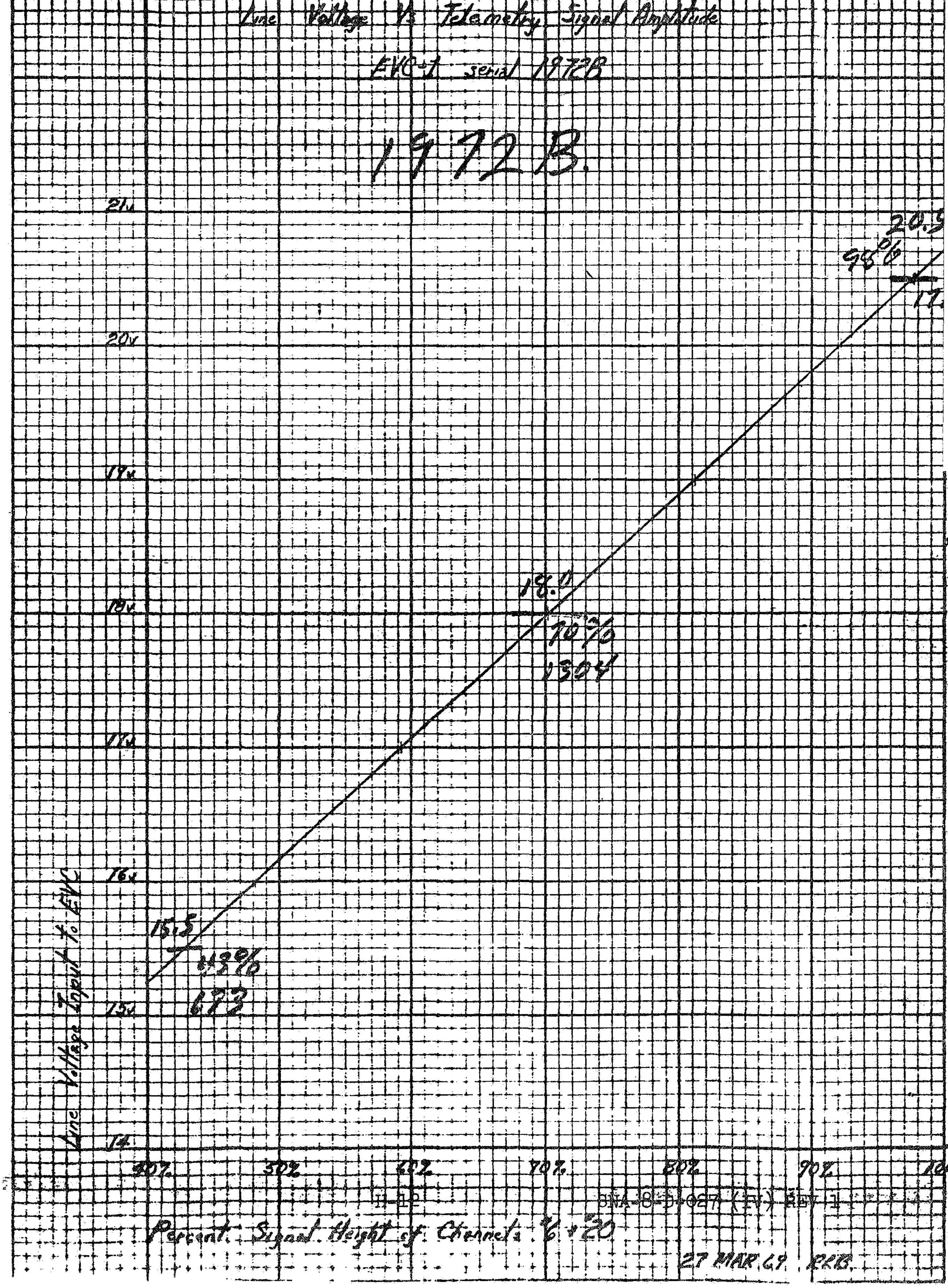
Volume IV EMU Data Book
PGA and Accessories Characteristics - Mission H-1

Purge Valve 139

Flow Rate = 7.9 lbs/hr O_2 at $90^{\circ}F$

Leakage Rate = 0 scc/minute at 3.85 ± .15 psig

PLSS 00019E00018



PLSS
S/N 00019

Low Pressure O_2 Loop Leakage	0 SCC/Min.
POS Leakage	0.21 psi/hr
Regulator Internal Leakage	1 SCC/Min
OPS Back Flow Check Valve Leakage	0.9 pph
Feedwater Loop External Leakage	0.0016 in H_2O/Min.
Feedwater to O_2 Leakage	56 SCC /Min.
Feedwater and Transport Loop Leakage	1.34 cc/hr
Transport Loop Leakage	0.27 cc/hr
Water Shutoff and Relief	Relief 57 psig Reseat 54 psig
Feedwater Quantity	8.500 pounds
High O_2 Flow Sensor	Actuation 0.55 pph Deactuation 0.60 pph
Low Vent Flow Sensor	Actuation 4.42 acfm Deactuation 4.45 acfm
Low PGA Pressure Switch	Actuation 3.19 psid Deactuation 3.28 psid
Low Feedwater Pressure Switch	Actuation 1.45 psia Deactuation 1.55 psia

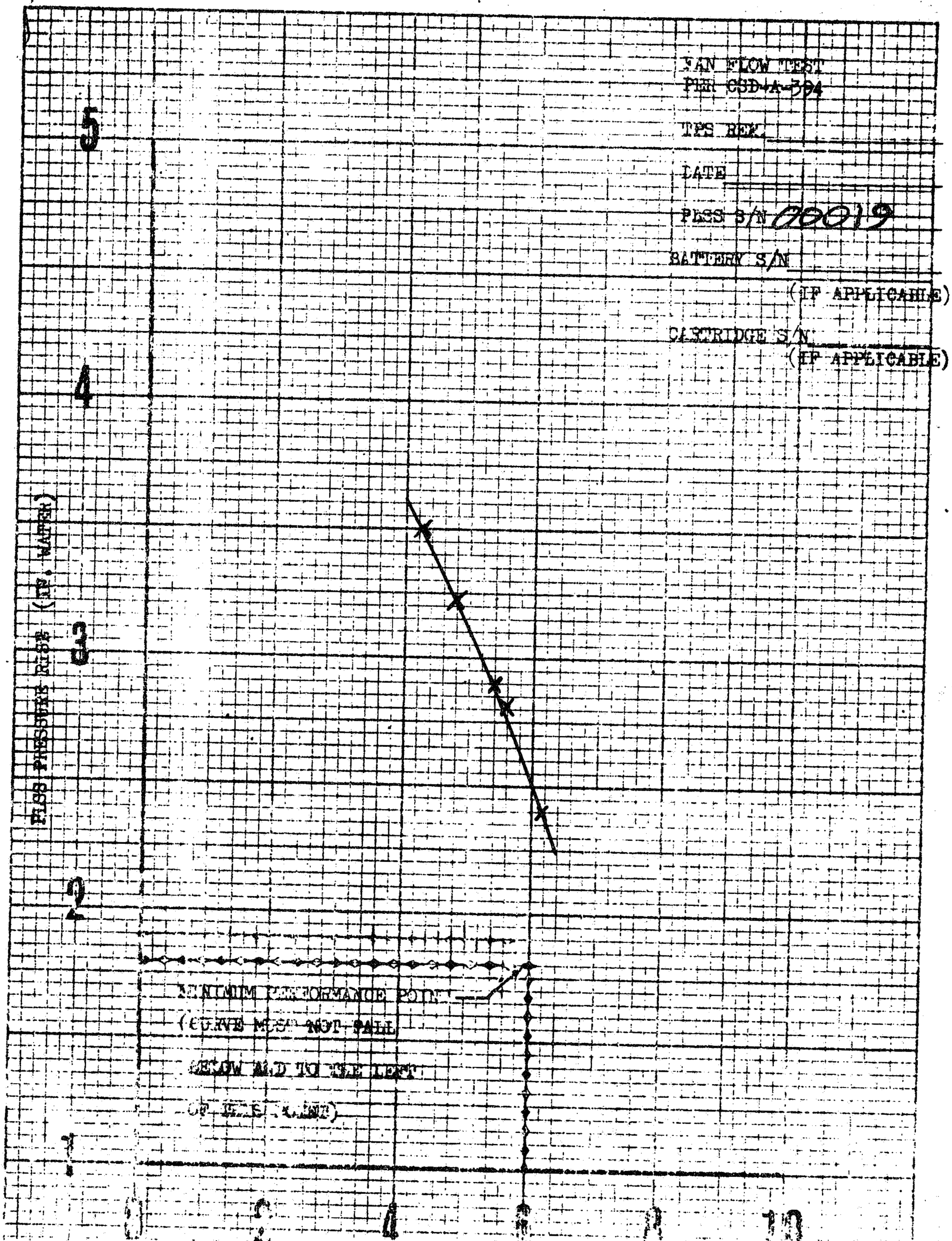
PLSS 019

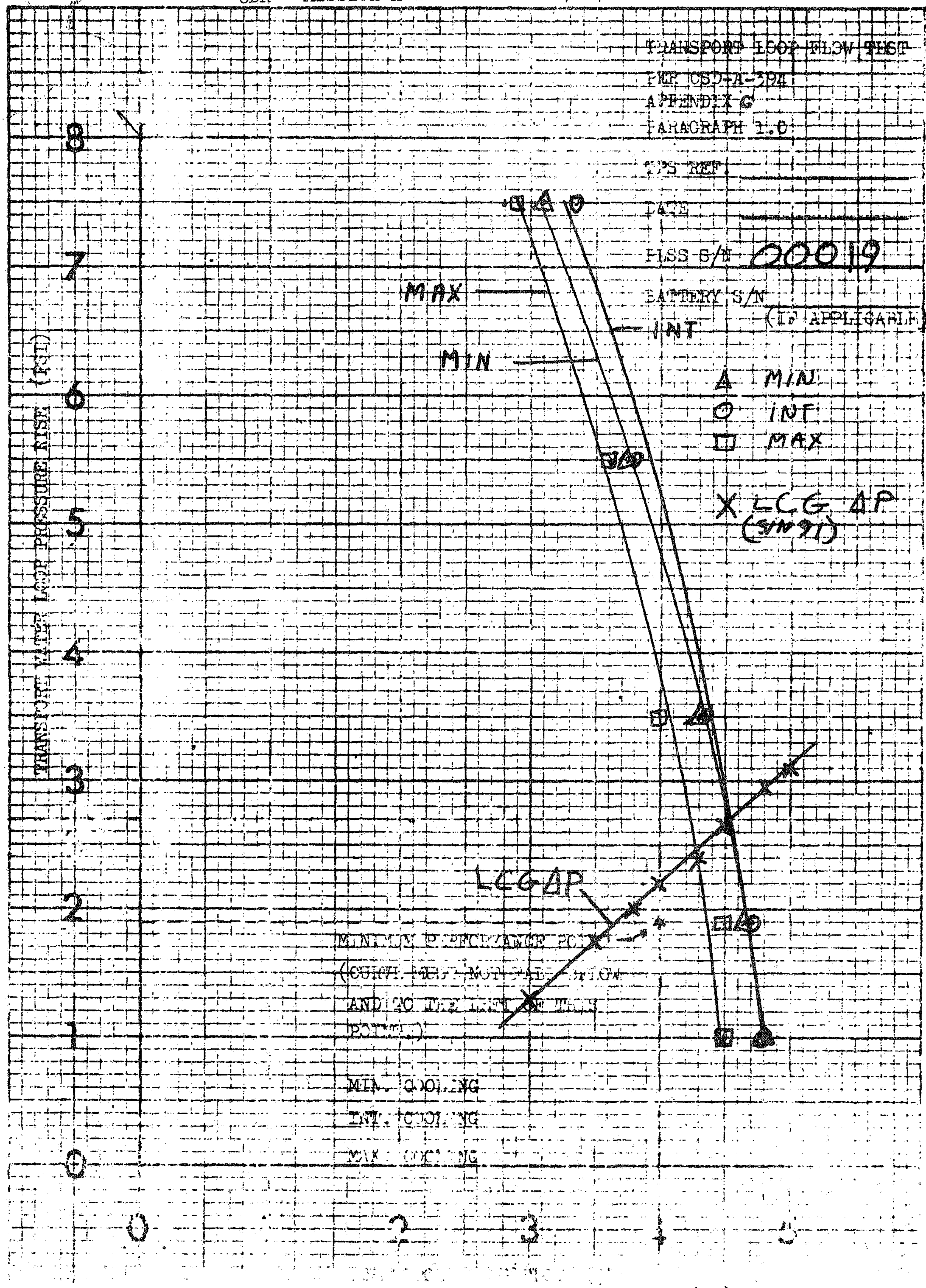
O_2 Regulation Performance

Bottle Pressure (psig)	Flow (lb/hr)	Regulated Pressure (psid)
85	.07	3.87
85	.35	3.84
85	.07	3.86
230	.075	3.88
230	.70	3.85
230	.08	3.86
1106	.08	3.89
1100	1.98	3.78
1105	.08	3.88

Pump Performance - See curve.

Fan Performance - See curve.


FAN FLOW TEST
PER CSD-A-394
TPS REF.
DATE
PLSS S/N 00019
BATTERY S/N
(IF APPLICABLE)
CARTRIDGE S/N
(IF APPLICABLE)
5
4
3
2
PLSS PRESSURE RISE (IN. WATER)
MINIMUM PERFORMANCE POINT
(CURVE MUST NOT FALL
BELOW AND TO THE LEFT
OF THIS POINT)
0
2
4
6
8
10


TRANSPORT LOOP FLOW TEST
REF CSD-A-394
APPENDIX G
PARAGRAPH 1.0
CPS REF
DATE
PLSS S/N 00019
BATTERY S/N
(IF APPLICABLE)
MAX
INT
MIN
MIN
INT
MAX
LCG ΔP
(S/N 91)
LCG ΔP
MINIMUM PERFORMANCE POINT
(CURVE MUST NOT FALL BELOW AND TO THE LEFT OF THIS POINT.)
MIN. COOLING
INT. COOLING
MAX. COOLING
TRANSPORT WATER LOOP PRESSURE RISE (PSI)
8
7
6
5
4
3
2
1
0
0
2
3
4
5

OPS PRE FLIGHT PIA DATA

KEY PERFORMANCE CHARACTERISTICS

OPS S/N 011 SV 730101-2-15

1. CHECKOUT GAGE ACCURACY

Actual Delta P	Indicated Delta P
3.5 psid	3.4 psid
3.8 psid	3.7 psid

2. LOW PRESSURE EXTERNAL LEAKAGE

Indicated Leakage 0.0000333 / .

Delta P 4.25 psid

3. HIGH PRESSURE EXTERNAL LEAKAGE

Indicated Leakage 0.00000015 /min.

Delta P Full Charge psid

4. INTERNAL LEAKAGE (ACROSS REGULATOR)

Indicated Leakage Less Than 1.0 cc/min.

5. PURGE FLOW PERFORMANCE FOR THIRTY-MINUTE FLOW AT 8.3 LB/HR FLOW RATE

Bottle Pressure - Start 5900 psig

Stop 1100 psig

Regulator Delta P During Run

Maximum 3.67 psid

Minimum 3.60 psid

6. MAKE-UP FLOW PERFORMANCE

Bottle Pressure 6750 psig

Flow Rate 0.08 lb/hr

Regulated Delta P Range 3.72 PSIA

Maximum ______ psid

Minimum ______ psid

APOLLO XII

FLIGHT PGA CHECKOUT DATA

Conrad
CREWMAN

A7L-065
PGA S/N

ITEM	SPEC. REQUIREMENT	FACTORY PDA	CAT PIA	FLIGHT PIA	FLIGHT DAY	REMARKS
1) Relief Valve	S/N 2025			1st | 2nd		
Crack	5.5 psi			5.12 | 5.05		
Reseat	4.8 psi			4.86 | 4.88		
Flowrate				5.75 scfm		
2) Pressure Gage	S/N 231					
3.0 psi	± .15 psi			3.04		
3.5 psi	± .15 psi			3.54		
4.0 psi	± .15 psi			4.03		
4.5 psi	± .15 psi			4.52		
5.0 psi	± .15 psi			5.02		
5.5 ~~6.0~~ psi	± .15 psi			5.52		
6.0 ~~3.75~~ psi	± .15 psi			6.03		
3) Leakage						
0.2 psi	180 scc			16.5 scc/m		
3.75 psi	180 scc			105 scc/min		
4) Pressure Drop						
ΔP (in H_2O)				3.0	8.2	
Flowrate scfm				6.0	12.0	
Suit press. psia				18.7 PSIA	18.2 PSIA	
				EV mode	IV mode	

CSD MISSION MANAGER

DATE

FLIGHT LCG CHECKOUT DATA

C. Conrad
CREWMAN

091
LCG S/N

ITEM	SPEC. REQUIREMENT	FACTORY PDA	CAT PIA	FLIGHT PIA	FLIGHT ~~DAY~~ CHARGE	REMARKS
Dry Weight	gms				1648 gms	
Wet weight	gms				1936 gms	
Charge Pressure	psig				13.8 PSIG	
Charge Date/Time					11 Nov 69 0315	
Pressure drop at Flowrate indicated		psid				
	3.0 ± .1 lb/min	______		1.33		
	3.5 ± .1 lb/min	______		1.75		
	3.8 ± .1 lb/min	______		2.0		
	4.0 ± .1 lb/min	______		2.2		
	4.3 ± .1 lb/min	______		2.39		
	4.5 ± .1 lb/min	______		2.65		
	4.8			2.95		
	5.0 ± .1 lb/min	______		3.1		

____
[illegible] MISSION MANAGER

____
DATE

Volume IV EMU Data Book
PGA and Accessories Characteristics - Mission H-1

Purge Valve 138

Flow Rate = 8.0 lbs/hr O_2 at 90°F

Leakage Rate = 0 scc/minute at 3.85 ± .15 psig

APOLLO 12 CRITICAL DATA S MMARY SHEET

	PLSS 018	PLSS 019	PLSS	)PS 011	OPS 018	OPS
Dry Weight* (lbs.)	54.733	55.750		29.875	30.188	
Charged Weight** (lbs.)	79.749	79.371		40.125	40.625	
O_2 Pressure (psia)(70°F)	1030	1020		5815	5815	
Battery Activation Date	11-10-69	11-10-69		11-6-69	11-7-69	
Lanyard Slide (in.)	-	-		0.615	0.034	
Switch Overtravel (in.)	-	-		0.017	0.012	
F/W Quantity (lbs.)	8.500	8.563		--	--	
T/W Quantity (lbs.)	1.375	1.375		--	--	
LiOH Weight (lbs.)	4.677	4.522		--	--	
RCU Weight (lbs.)	5.067	5.063		--	--	
Battery Shelf Life	12 Days	12 Days		23 Days	23 Days	
RCU Serial Number	00021	00016		--	--	
Battery Serial Number	S-181	S-183		S-61	S-60	
LiOH Cartridge Serial Number	00104	00110		--	--	

* Less RCU, Thermal Cover, Harness, Battery and Cartridge

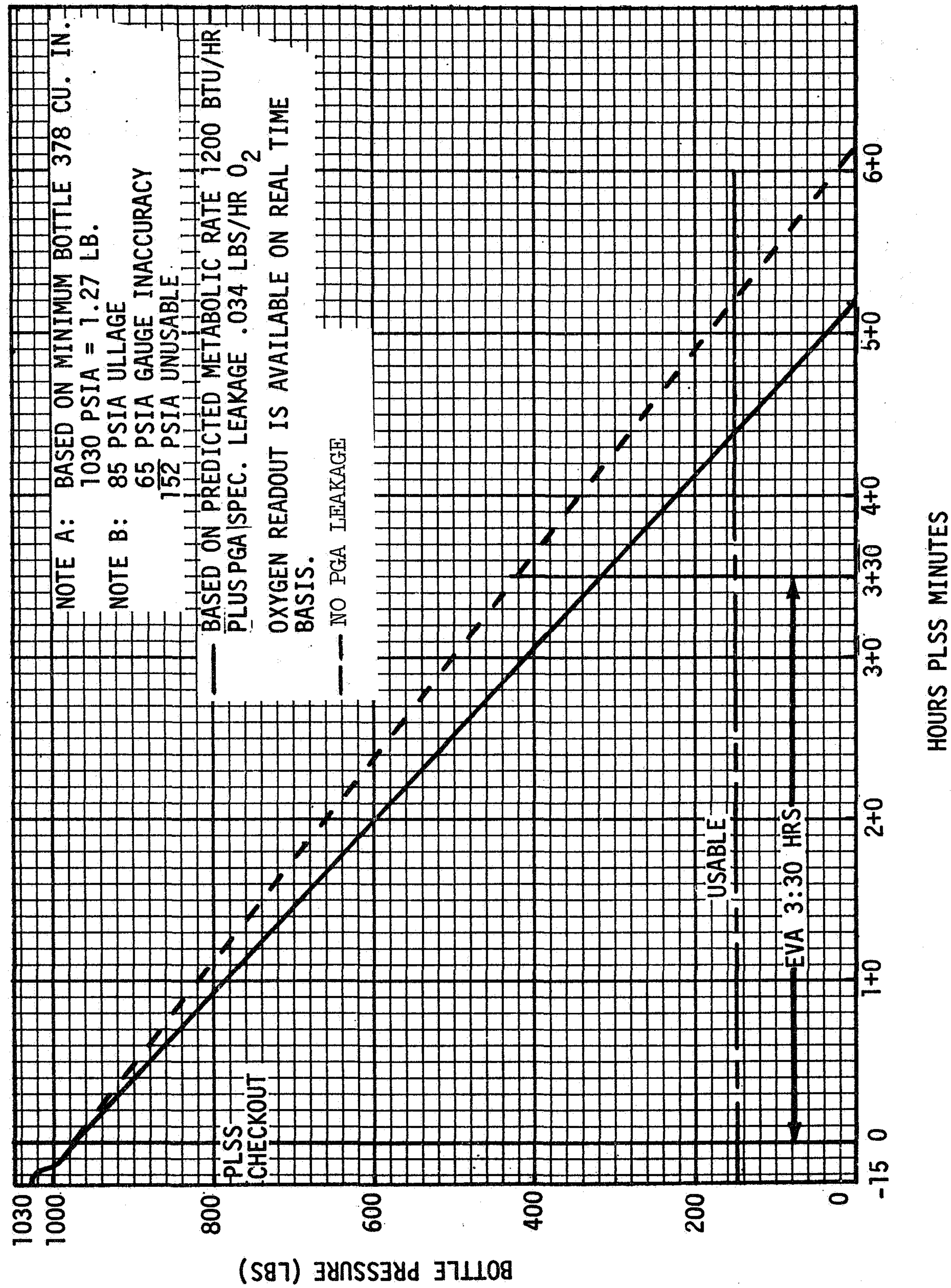
** Completely Flight Configured, les RCU

Predicted Lunar Surface EVA Walking Metabolic Rates

Various activities such as Environmental Familiarization, ALSEP Return Traverse, Geological Traverse, Complete Geological Traverse are considered to be primarily walking modes of activity. The average metabolic rate for these activities based on predicted and real-time estimates is 1050 BTU/hour. It should be understood that this prediction is subject to future revision as further data becomes available. At present, data have not been obtained on Geological Traverses ·nd ALSEP Traverses. Also, changes from expected walking speeds or terrains would affect the prediction.

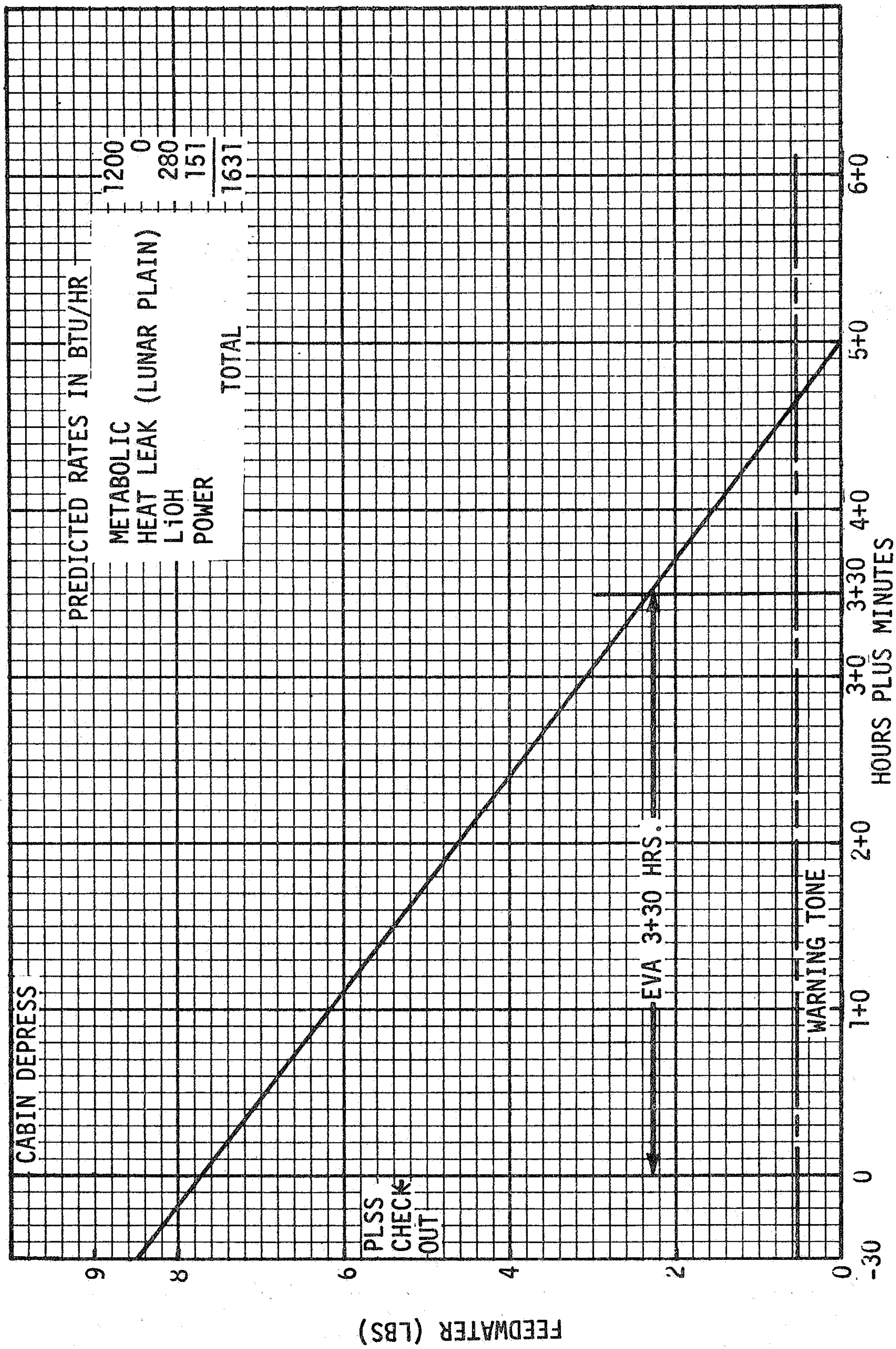
NOMINAL LUNAR SURFACE EVA #1

FIGURE 4-15. - CDR AND LMP - PLSS OXYGEN



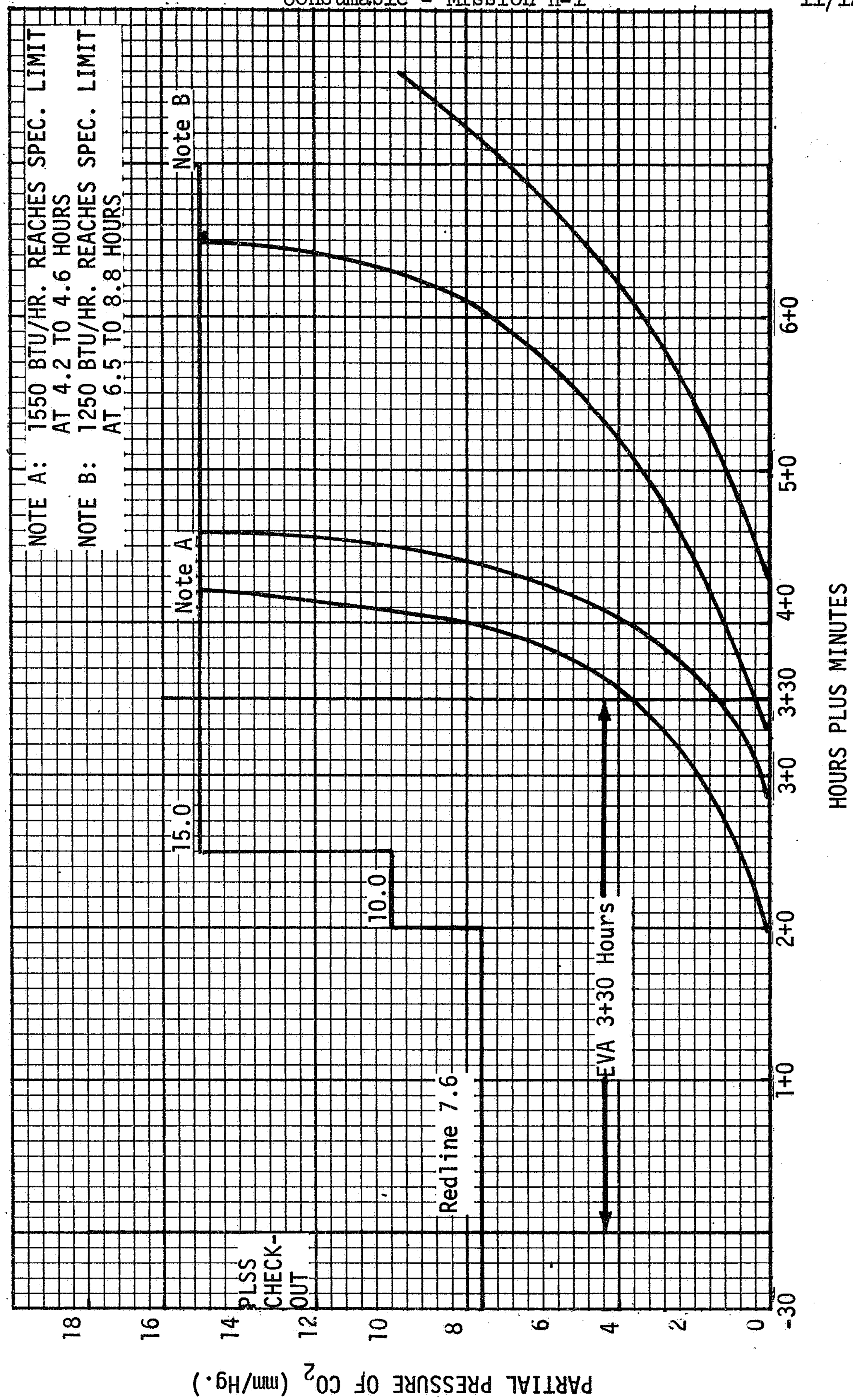
NOMINAL LUNAR SURFACE EVA #1 AND #2

Figure 4-14. - CDR AND LMP - PLSS WATER



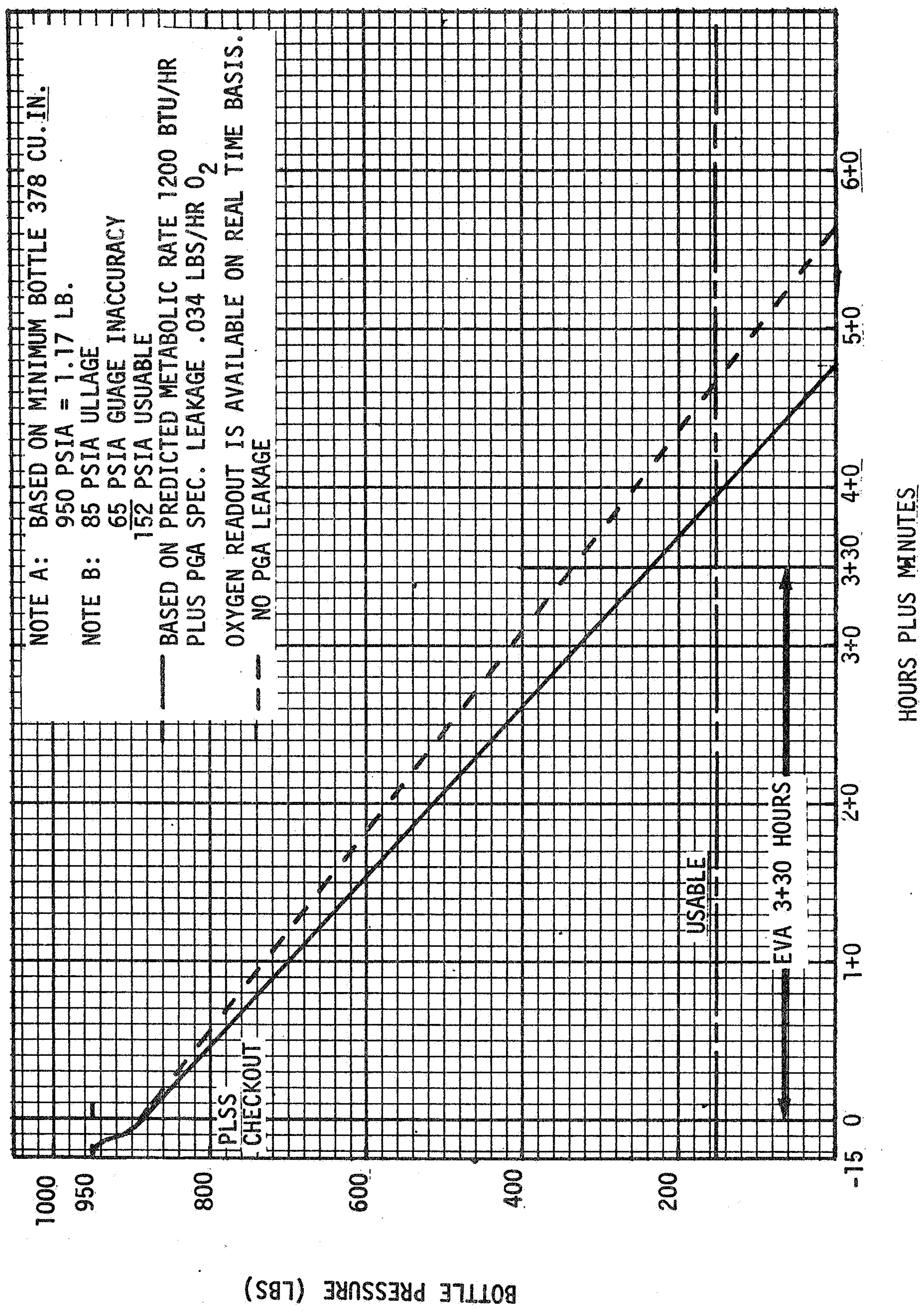
NOTE: IF THE CREWMAN LEAVES THE S/C WITH HEAT STORAGE AND RETURNS SUBCOOLED, HE WILL USE MORE H_2O THAN HIS METABOLIC O_2 CONSUMPTION INDICATES

NOMINAL LUNAR SURFACE EVA #1 AND #2
FIGURE 4-17. - CDR AND LMP - PLSS LiOH



NOMINAL LUNAR SURFACE EVA #2

Figure 4-16. - CDR AND LMP - PLSS OXYGEN



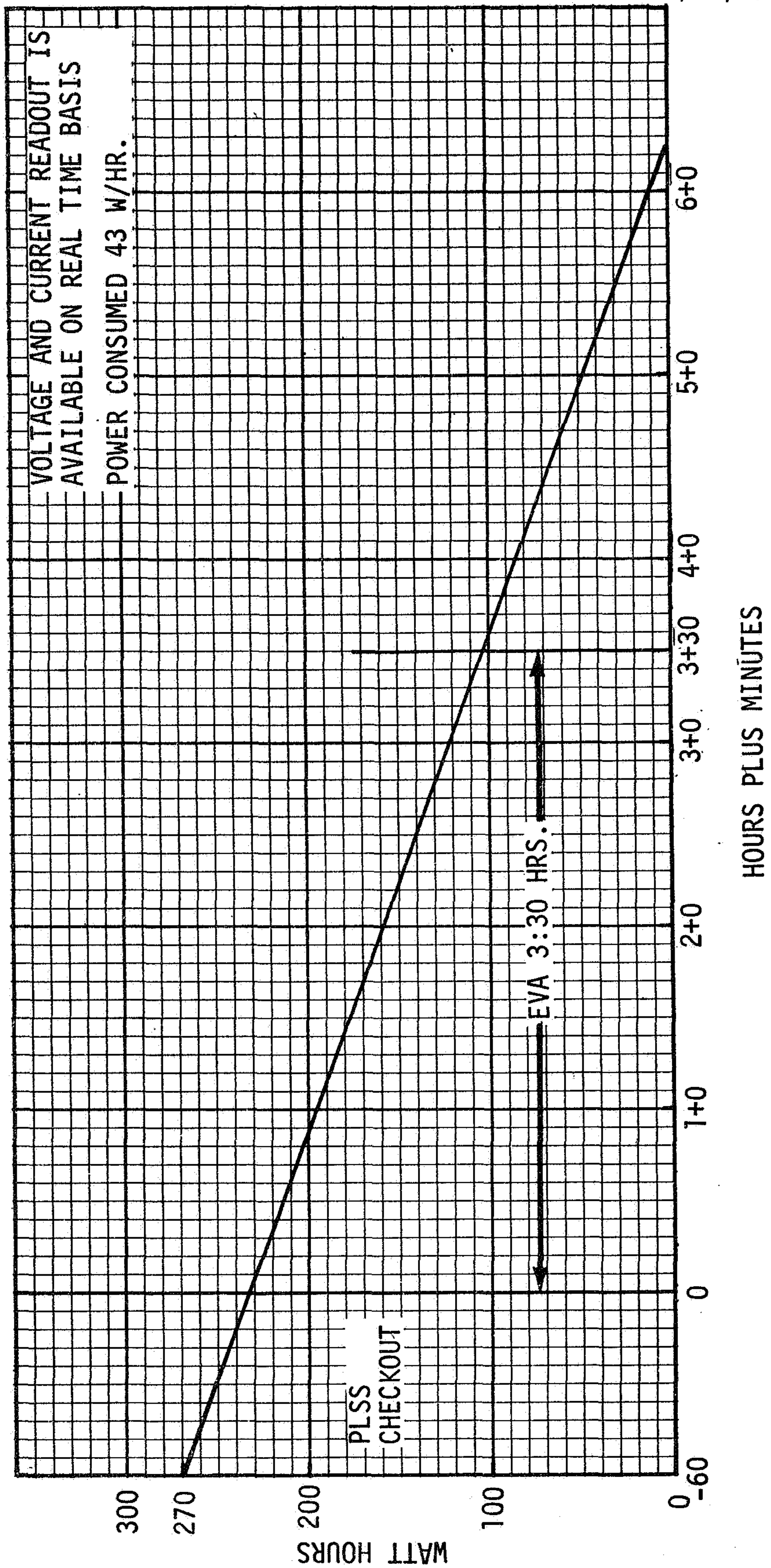


FIGURE 4-18. - CDR AND LMP - PLSS BATTERY

NOMINAL LUNAR SURFACE EVA #1 AND #2

H-2 MISSION APPENDIX

APOLLO 13

CONTENTS

Loading Chart — Page H2-2
Consumables — Page H2-4
Performance — Page H2-10
- PLSS — Page H2-10
- OPS — Page H2-26
- PGA — Page H2-38
- LCG — Page H2-39
- Purge Valve — Page H2-39
- Thermal — Page H2-40

CREW EQUIPMENT SERIAL NUMBERS

EQUIPMENT \ CREWMAN	CDR	LMP	CMP
PLSS*	021	020	---
OPS*	015	030	---
PGA	078	061	088
LCG	095	086	---
LEVA*	010	015	---
Purge Valve*	146	147	---

*INTERCHANGEABLE BETWEEN CREWMEN

LOADING CHART

	SPEC WGT	CDR S/N	CDR WGT LBS	IMP S/N	IMP WGT LBS	CMP S/N	CMP WGT LBS
EV/PGA with ITMG (including IV Gloves, Helmet, and Comm Carriers, EV Gloves, Lunar Boots)	55.29	078	53.79	061	53.49		
IV/PGA with IVCL (including IV Gloves, Helmet, and Comm Carriers)	37.15					082	37.64
LCG - Dry		095	3.833	086	4.131		
Wet	5.00	095	4.509	086	4.806		
H20 Wt.		095	0.677	086	0.679		
CWG	0.90	1144	.77	1230	.77	1293	.77
FCS	0.50	113	.38	115	.37	109	.32
UCTA	0.53	3963	.47	3965	.47	3964	.47
Bio-Belt	0.25	1399	.18	1408	.18	1403	.18
Bioinstrumentation Assembly	1.10	019	174.2gm	021	174.0gm	020	174.0gm
EV Gloves (pair)	2.5	075	2 lbs 7 oz	080	2 lbs 6 oz		
LEVA	5.90	010	5.75	015	5.75		
Helmet Protective Shield	0.95					085	.854
Lunar Boots	4.9		4 lbs 11 oz	035	4 lbs 9 oz		
Purge Valve	0.55	146	.494	147	.494		
PLSS, Dry* with O2 Charge		021	57.23	020	56.26		
PLSS, Fully Charged**	83.76 lbs_{max}	021	80.00	020	80.875		
Feedwater Quantity	8.30 lbs_{min}	021	8.59	020	8.53		
RCU	4.50 lbs_{max}	00019	5.11	00024	5.13		

LOADING CHART
(Continued)

	SPEC WGT	CDR		LMP		CMP	
		S/N	WGT LBS	S/N	WGT LBS	S/N	WGT LBS
Batteries, PLSS							
EVA I	5.55 lbs_{max}	S-198	5.3	S-190	5.52		
EVA II	5.55 lbs_{max}	S-206	5.48	S-209	5.47		
LiOH Cartridge							
EVA I	4.63 lbs_{max}	149	4.58	147	4.56		
EVA II	4.63 lbs_{max}	150	4.56	151	4.60		
OPS, Uncharged		015	30 lbs 4 oz	030	29 lbs 12 oz		
OPS, Fully Charged	41 lbs_{max}	015	40 lbs 11.2 oz	030	40 lbs 4.2 oz		
Batteries, OPS	2428gm	S-089	2139gm	S-086	2162gm		
Delta Weight = O_2		015	5.73 lbs	030	5.75 lbs		

* Less RCU, Thermal Cover, Harness, Battery, and Cartridge

** Completely Flight Configured, less RCU

CONSUMABLES

	SPEC	CDR	LMP
Batteries, PLSS			
EVA I			
S/N		S-198	S-190
Activation Date		4-7-70	4-7-70
Shelf Life		12 days	12 days
EVA II			
S/N		S-206	S-209
Activation Date		4-7-70	4-7-70
Shelf Life		12 days	12 days
LiOH Cartridge			
EVA I			
S/N		00149	00147
EVA II			
S/N		00150	00151
Feedwater Weight (lbs.)		8.59 lbs	8.53 lbs
Oxygen Pressure, PLSS (psia)	1020 ± 10 psia	1030 psia	1030 psia
Batteries, OPS			
S/N		S-089	S-086
Activation Date		4-3-70	4-3-70
Shelf Life		24 days	24 days
Oxygen Pressure, OPS (psia)	5880 ± 80 psi	5960 psi	5930 psi
OPS Gage	± 300	6100 psi	5990 psi

Apollo 13 PLSS Expendables

Main Power Supply

The main power supply has a two sigma power rating of 279 watt-hrs. With a PLSS power consumption of 43.5 watts, based upon Apollo 13 crew training exercises in SESL, the power supply will last 5.75 hours with the following checkout data:

Checkout	EVCS:	40 minutes @ 0.7 amps
	Fan :	30 minutes @ 2.0 amps
	Pump:	15 minutes @ 0.6 amps

NOTE: Above information based on voltage of 16.8 volts.

Feedwater

With an 8.5 lb charge and unusable water as follows, there is 7.54 lbs of usable feedwater.

Residual:	0.23 lbs
Slave :	0.60 lbs
Leakage :	0.13 lbs

See page H2-6 for curve of mission time versus metabolic rate.

Oxygen - EVA I

With a charge pressure of 1020 psia, there is 0.953 lbs (mass) usable. This is based on the following overhead requirements.

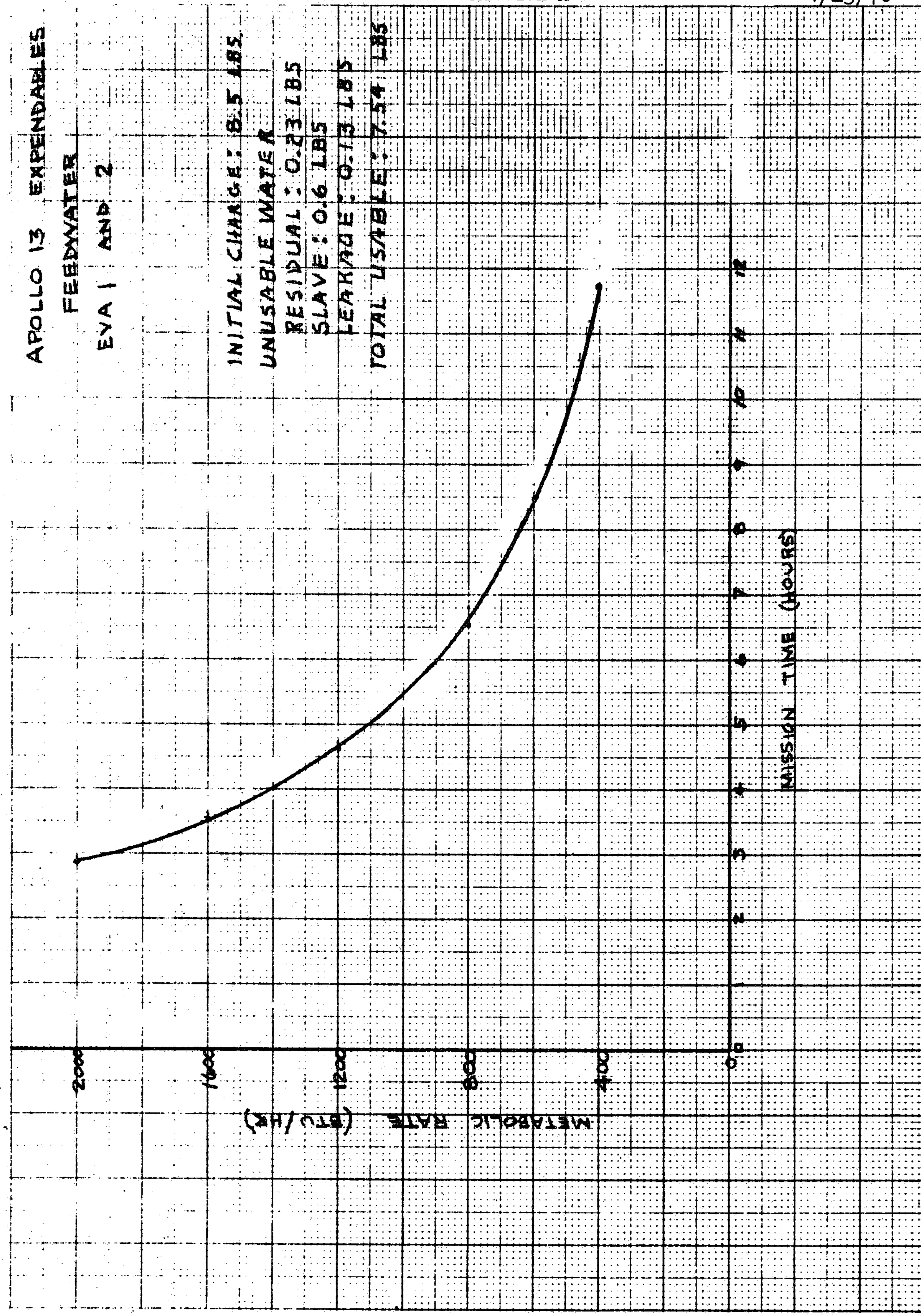
Instrument error:	50 psi
Leakage check:	36 psi
Metabolic (Fan on to Cabin Depress):	34 psi
Cabin Repress:	21 psi

See page H2-7 for curve of mission time versus metabolic rate.

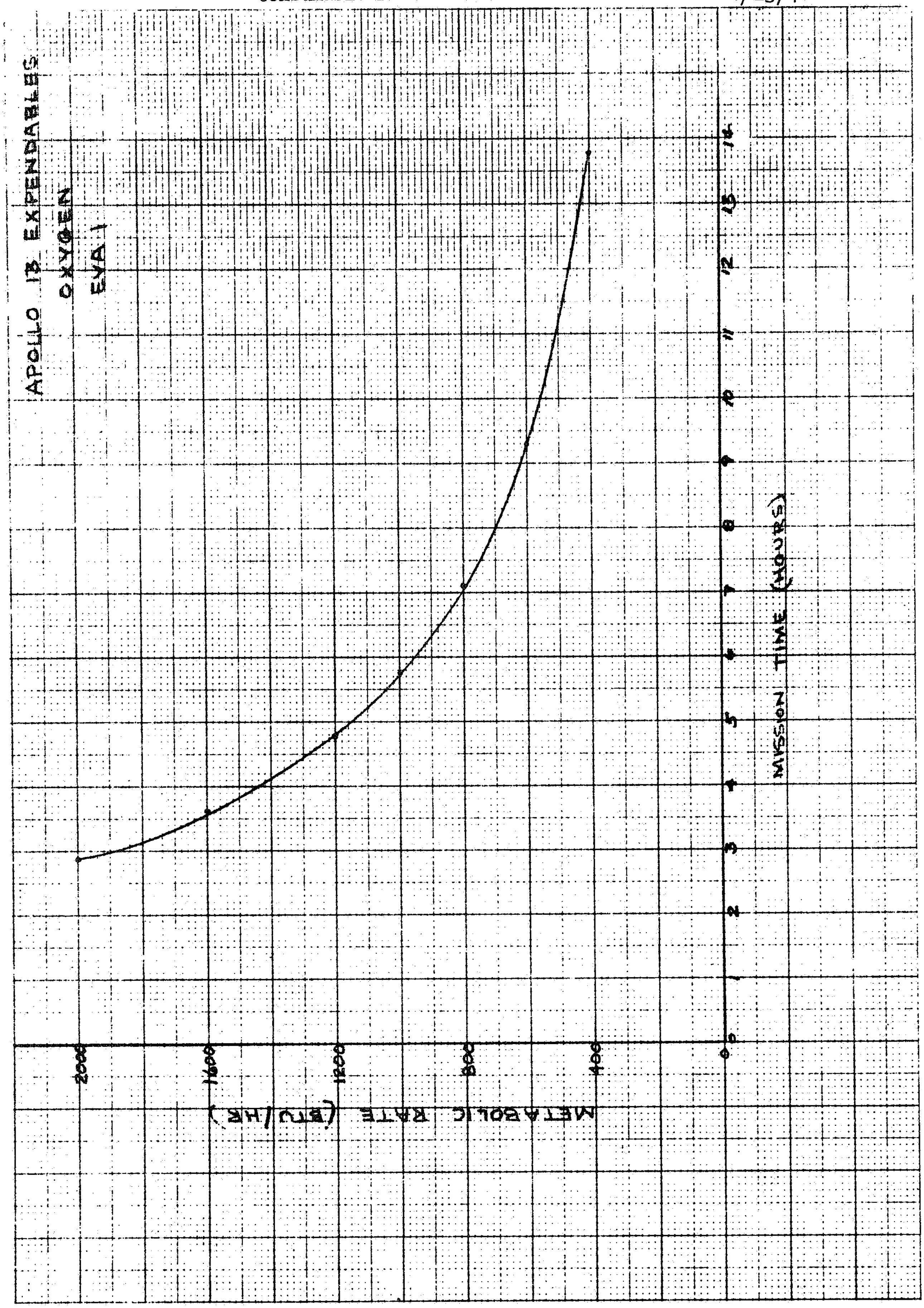
Oxygen - EVA II

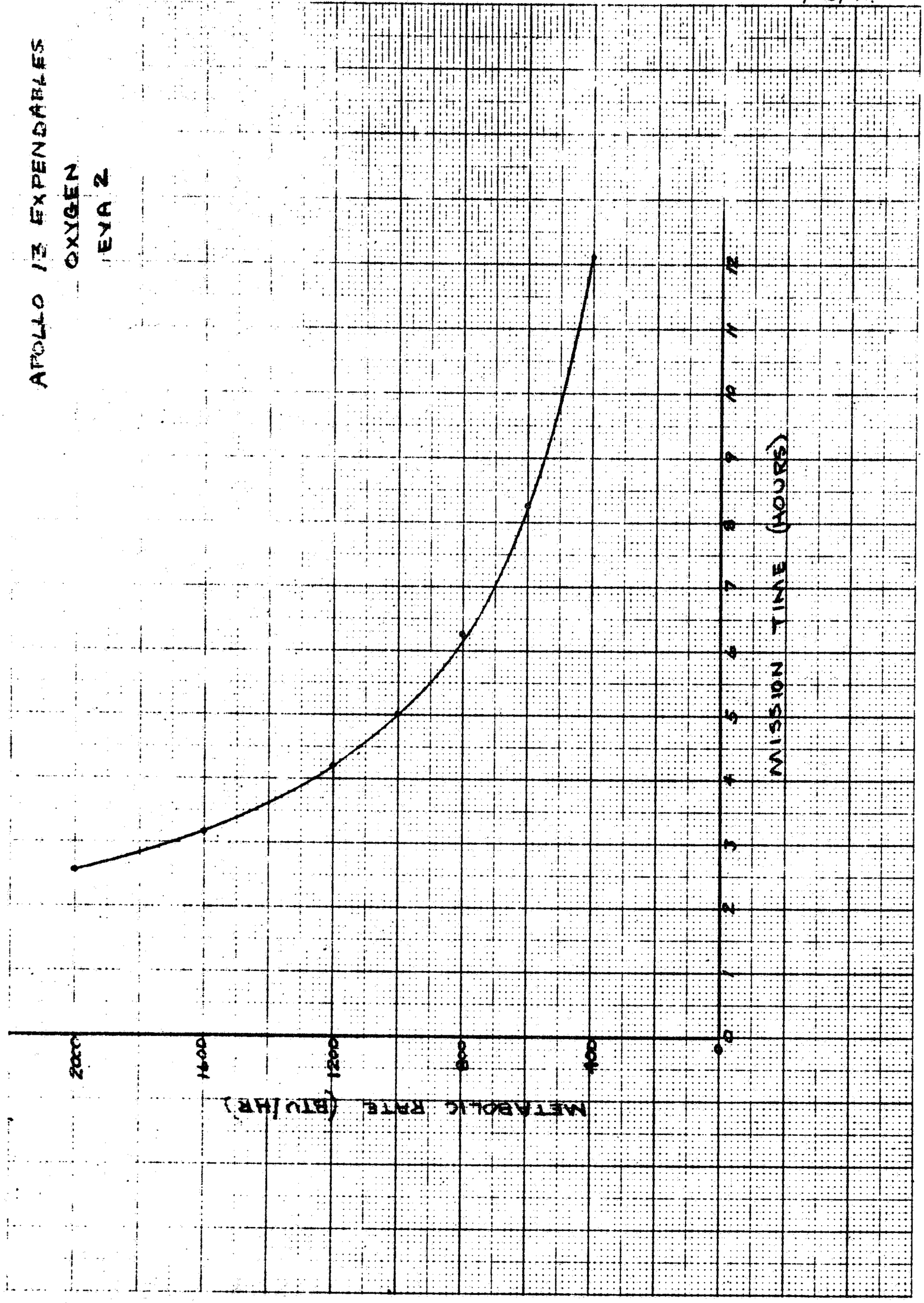
With a charge pressure of 927 psia, there is 0.838 lbs (mass) usable. This is based on the same overhead requirements as for EVA I. The charge pressure is based on a 942 psia LM regulator performance and a 15 psi loss due to PLSS bottle cool down.

See page H2-8 for curve of mission time versus metabolic rate.



BEE 20x20 TO INCH


APOLLO 13 EXPENDABLES
OXYGEN
EVA 1
MISSION TIME (HOURS)
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
METABOLIC RATE (BTU/HR)
2000
1600
1200
800
400
0



BEE 20x20 TO INCH

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		PERFORMANCE SPEC	CDR	LMP
PLSS				
-S/N			021	020
-Leakage				
Low Pressure O_2 Loop	(SSC/Min.)	20 SCC/Min Max.	0.0 SCC/Min	0.0
POS Pressure	(PSI/Hr)	.5 PSI/Hr	.42 PSI/Hr	.22 PSI/Hr
Regulator Internal	(SCC/Min.)	25 SCC/Min	0.0	0.0
OPS Backflow Check Valve	(Lbs/Hr)	.5 Lbs/Hr	Below .06 Lbs/Hr	Below .06 Lbs/Hr
External Feedwater	(In H_2O Min)	.034 In. H_2O/Min Max.	0.0	.00066 In. H_2O/Min.
Feedwater to O_2 Loop	(SCC/Min)	175 SCC/Min Max	82.5 SCC/Min	37 SCC/Min
Feedwater and Transport Loop	(CC/Hr)	1.65 CC/Hr Max	1.56 CC/Hr	1.45 CC/Hr
Liquid Transport Loop	(CC/Hr)	.27 CC/Hr Max	.16 CC/Hr	.05 CC/Hr
-Pressure Rise, Low Pressure O_2 Loop		N/A		
Fan performance at least five points of pressure rise vs flow at 3.85 ± 0.15 PSIA.				
1) (ACFM/In. H_2O)			5.50/3.28	5.5/2.9
2)			4.22/3.93	4.22/3.61
3)			4.75/3.63	4.74/3.26
4)			5.28/3.33	5.28/3.0
5)			6.04/2.86	6.02/2.5
6)			6.49/2.54	6.48/2.18
7)			0/4.90	0/4.87

PERFORMANCE

PLSS, (cont'd)		SPEC.	CDR.	LMP.
-Sensors			PLSS 021	PLSS 020
High O_2 Flow				
Actuation	(Lbs/Hr)	.50-.65 Lbs/Hr.	.51 Lbs/Hr.	.525 Lbs/Hr.
Deactuation	(Lbs/Hr)	.50-.65 Lbs/Hr.	.50 Lbs/Hr.	.51 Lbs/Hr.
Low Vent Flow				
Actuation	(ACFM)	4.45-5.3 ACFM	4.45 ACFM 4.51 ACFM	4.45 ACFM 4.53 ACFM
Deactuation	(ACFM)			
Low PGA Pressure				
Actuation	(PSID)	3.10-3.40 PSID	3.20 PSID	3.22 PSID
Deactuation	(PSID)	3.40-3.10 PSID	3.25 PSID	3.28 PSID
Low Feedwater Pressure				
Actuation	(PSIA)	1.30 PSIA	1.35 PSIA	1.43 PSIA
Deactuation	(PSIA)	1.60 PSIA	1.39 PSIA	1.52 PSIA

		PERFORMANCE SPEC.	CDR. PLSS	LMP. PLSS
PLSS, (cont'd)				
-Oxygen Regulator Characteristics			021	020
Give three regulation points at Low, High, and Low flows for three bottle pressures:				
Bottle Pressure 100 PSIA				
1) (Lbs/Hr/PSID)	.070-.080 Lbs /Hr	3.90±0.15	3.87 PSID	3.84 PSID
2)	.35-.36 Lbs/Hr	3.90±0.15	3.82 PSID	3.82 PSID
3)	.070-.080 Lbs/Hr	3.90±0.15	3.88 PSID	3.84 PSID
Bottle Pressure 250 PSIA				
1) (Lbs/Hr/PSID)	.070-.080 Lbs/Hr	3.90±0.15	3.90 PSID	3.86 PSID
2)	.65-.75 Lbs /Hr	3.90±0.15	3.84 PSID	3.84 PSID
3)	.070-.080 Lbs./Hr	3.90±0.15	3.89 PSID	3.85 PSID
Bottle Pressure 1120 PSIA				
1)	.070-.080 Lbs /Hr	3.90±0.15	3.89 PSID	3.88 PSID
2)	1.90-2.0 Lbs /Hr	3.80±0.25	3.74 PSID	3.74 PSID
3)	.070-.080 Lbs./Hr	3.90±0.15	3.88 PSID	3.87 PSID
-Feedwater Vent Orifice				
Flow at 49 PSID (CC/Min)		400-1400CC/ 2 Mins.	1250 CC/ 2 Mins.	1200 CC/ 2 Mins.
Flow at 49 PSID (Lbs/Min)				
-Stowage Plate Relief Valve				
Cracking Pressure		4.5-6.0 PSID	6.0 PSID	5.2 PSID

		PERFORMANCE SPEC.		CDR.	LMP.
PLSS, (cont'd)				PLSS	PLSS
-Pressure Rise, Liquid Transport Loop (Pump Performance) at least three points, for each Diverter Valve position, of Flow vs Pressure Rise:				021	020
Minimum Diverter Valve Position					
1)	(Lbs/Min./PSI)	3.7 Lbs/Min Min	1.9+0.1 -0.0	4.55 Lbs/Min 1.9 ΔP	4.5 Lbs/Min 1.9 ΔP
2)		↑	7.5±0.1	1.25 Lbs/Min 7.5 ΔP	2.6 Lbs/Min 7.5 ΔP
3)		N/A	5.5±0.1	3.0 Lbs/Min 5.5 ΔP	3.4 Lbs/Min 5.5 ΔP
4)			3.5±0.1	4.1 Lbs/Min 3.5 ΔP	4.0 Lbs/Min 3.5 ΔP
5)		↓	1.0±0.1	4.85 Lbs/Min 1.0 ΔP	4.7 Lbs/Min 1.0 ΔP
Intermediate Diverter Valve Position					
1)	(Lbs/Min./PSI)	3.7 Lbs/Min Min.	1.9+0.1 -0.0	4.75 Lbs/Min 1.9 ΔP	4.5 Lbs/Min 1.9 ΔP
2)		↑	7.5±0.1	1.3 Lbs/Min 7.5 ΔP	2.8 Lbs/Min 7.5 ΔP
3)		N/A	5.5±0.1	3.15 Lbs/Min 5.5 ΔP	3.6 Lbs/Min 5.5 ΔP
4)			3.5±0.1	4.25 Lbs/Min 3.5 ΔP	4.0 Lbs/Min 3.5 ΔP
5)		↓	1.0±0.1	4.85 Lbs/Min 1.0 ΔP	4.7 Lbs/Min 1.0 ΔP
Maximum Diverter Valve Position					
1)	(Lbs/Min./PSI)	3.7 Lbs/Min Min	1.9+0.1	4.8 Lbs/Min 1.9 ΔP	4.0 Lbs/Min 1.9 ΔP
2)		↑	7.5±0.1	2.2 Lbs/Min 7.52 ΔP	2.4 Lbs/Min 7.5 ΔP
3)		N/A	5.5±0.1	3.0 Lbs/Min 5.5 ΔP	3.0 Lbs/Min 5.5 ΔP
4)		↓	3.5±0.1	3.9 Lbs/Min 3.5 ΔP	3.85 Lbs/Min 3.5 ΔP

(cont.)

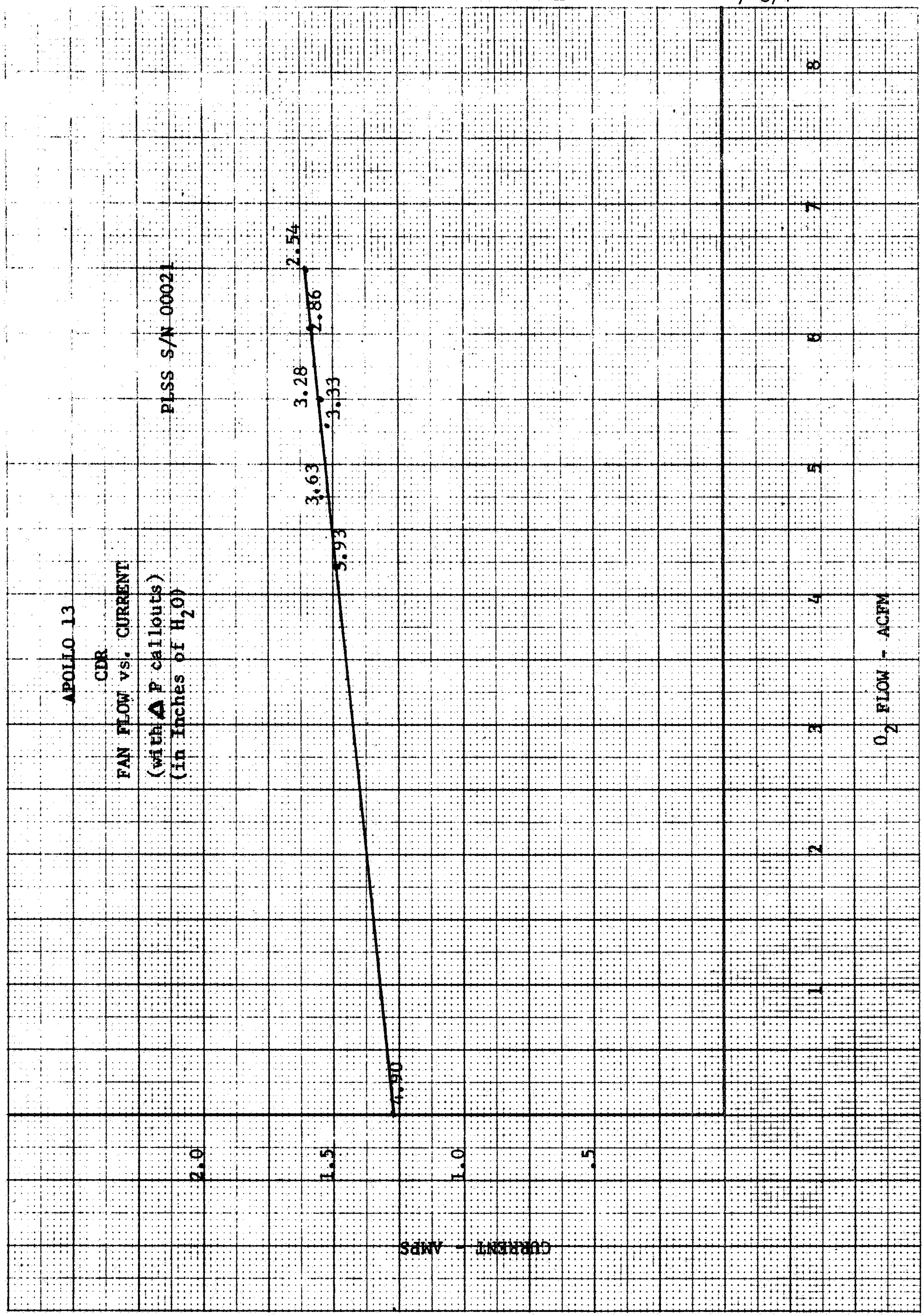
PERFORMANCE

	SPEC.	CDR.	LMP.
PLSS, (cont'd)		PLSS	PLSS
5)	1.0±0.1	4.75 Lbs/Min 1.0 ΔP	4.4 Lbs/Min 1.0 ΔP
-Water Shutoff and Relief Valve			
Relief Pressure (PSID)	52.0-65.0 PSIG	63.0 PSIG	64.0 PSIG
Reseat Pressure (PSID).	40.0 Min.	52.0 PSIG	58.5 PSIG

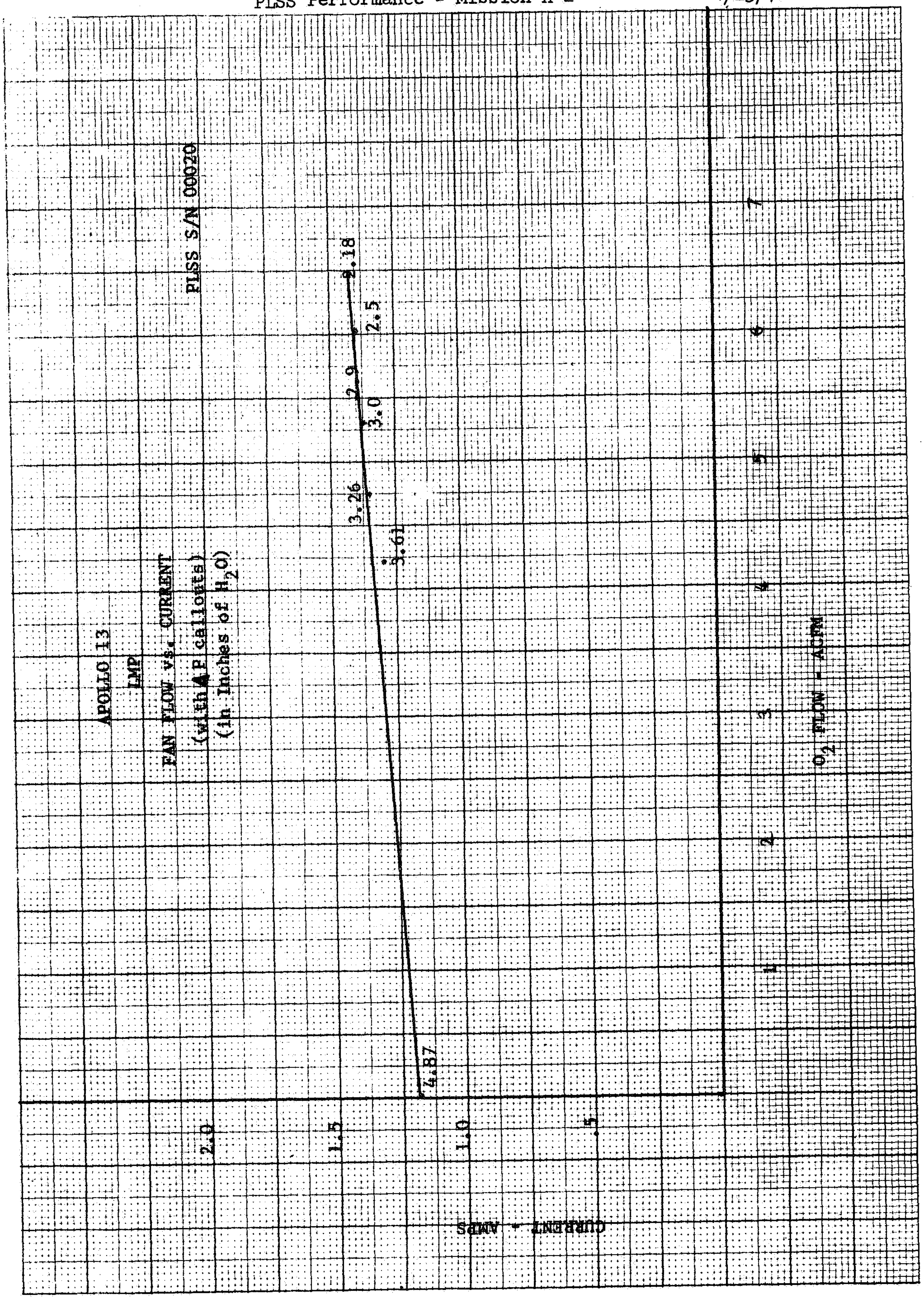
APOLLO 13

TRANSDUCER END TO END CALIBRATION

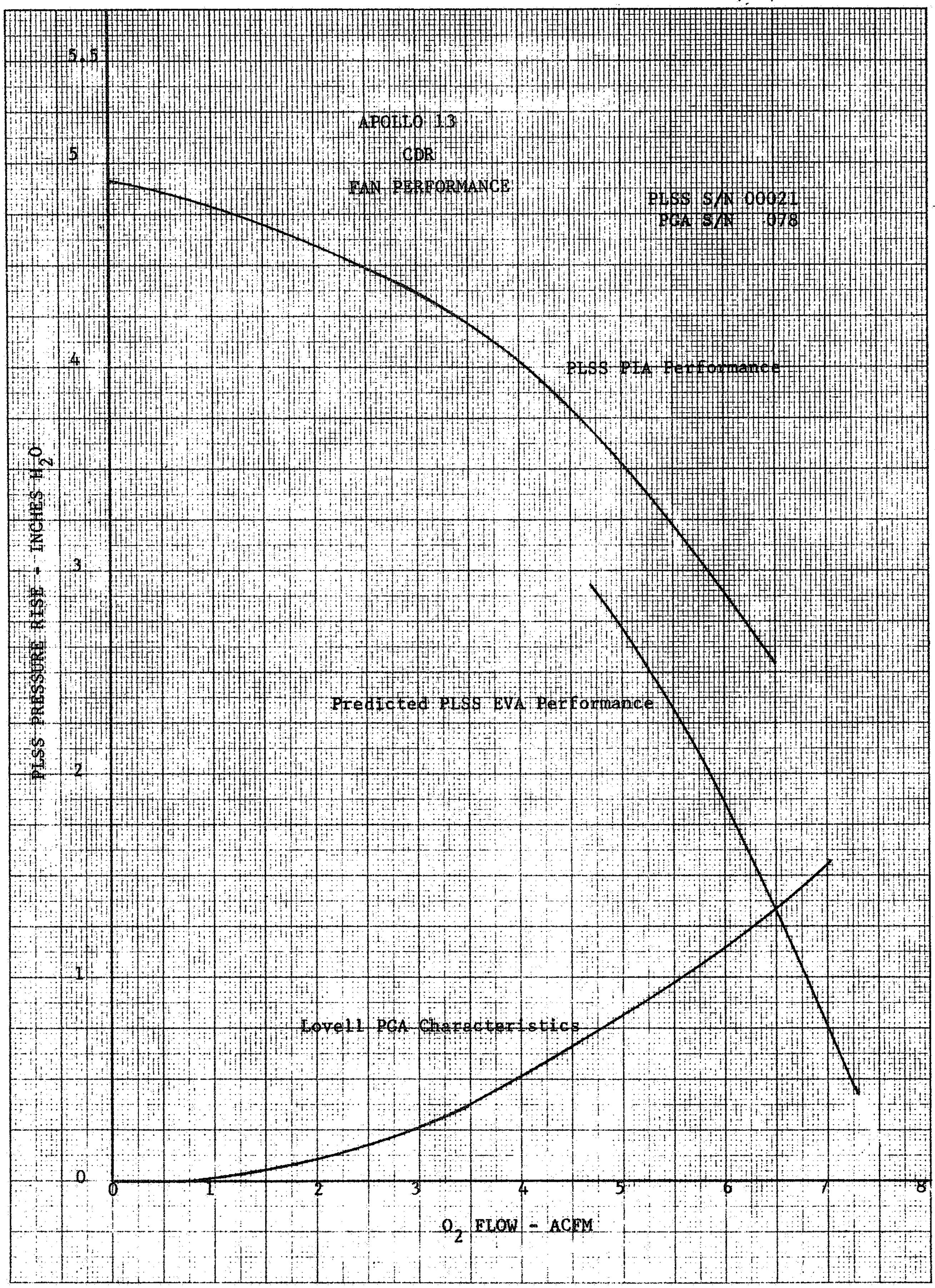
PARAMETER	SPEC	CDR		LMP	
		Actual Input	TM Output	Actual Input	TM Output
PGA Pressure	2.95-3.13 PSID	3.0 PSID	3.025 PSID	3.0 PSID	3.06 PSID
	3.9-4.1 PSID	4.0 PSID	4.0 PSID	4.0 PSID	4.05 PSID
Feedwater Pressure	1-1.25 PSIA	1.0 PSIA	1.10 PSIA	1.0 PSIA	.90 PSIA
	3.56-3.83 PSIA	3.66 PSIA	3.70 PSIA	3.66 PSIA	3.63 PSIA
LCG Inlet Temp	70°F-75.25°F	72.3 °F	72.5 °F	73 °F	73.0 °F
	71°F-86.2°F	73.2 °F	73.5 °F	74.5 °F	75.0 °F
Sub. Gas Out. Temp.	70°F-75.25°F	72.3 °F	72.5 °F	73 °F	73.0 °F
	71°F-86.2°F	73.2 °F	73.5 °F	74.5 °F	75.0 °F
Battery Current	.55-.65 AMPS	.6 amps	.6 amps	.6 amps	.6 amps
Battery Voltage	15.8-17.8 volts	16.65 volts	16.7 volts	16.75 volts	16.75 volts
POS Pressure	915-980 PSIA	961 PSIA	955 PSIA	961 PSIA	944 PSIA
	597 1/2 - 661 PSIA	611 PSIA	633 PSIA	611 PSIA	611 PSIA
	137 1/2 - 200 PSIA	161 PSIA	178 PSIA	161 PSIA	155 PSIA

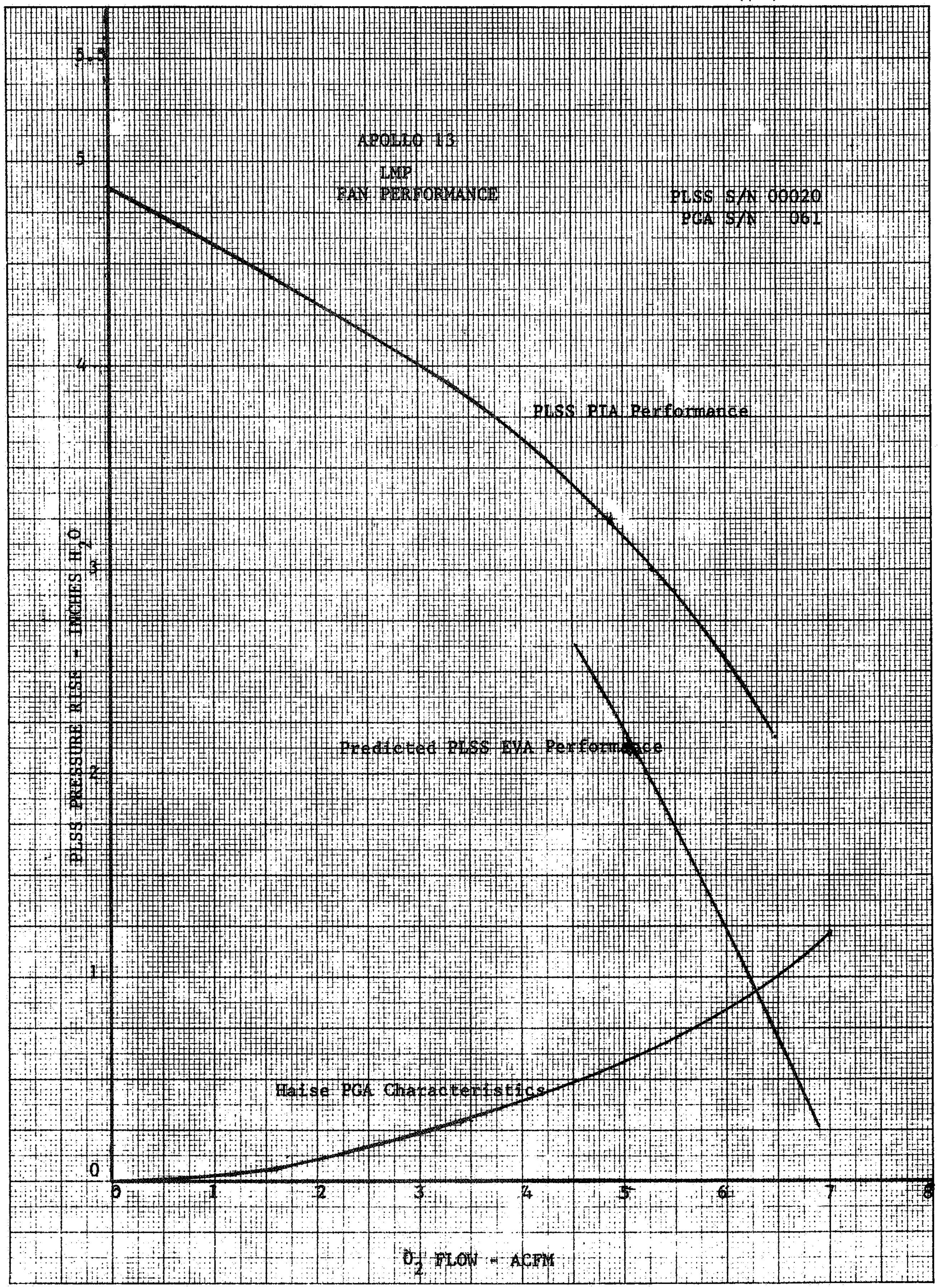

APOLLO 13
CDR
FAN FLOW vs. CURRENT
(with Δ P callouts)
(in inches of H_2O)
PLSS S/N 00021
2.54
2.86
3.28
3.33
3.63
3.93
4.90
8
7
6
5
4
3
2
1
O_2 FLOW - ACFM
2.0
1.5
1.0
.5
CURRENT - AMPS

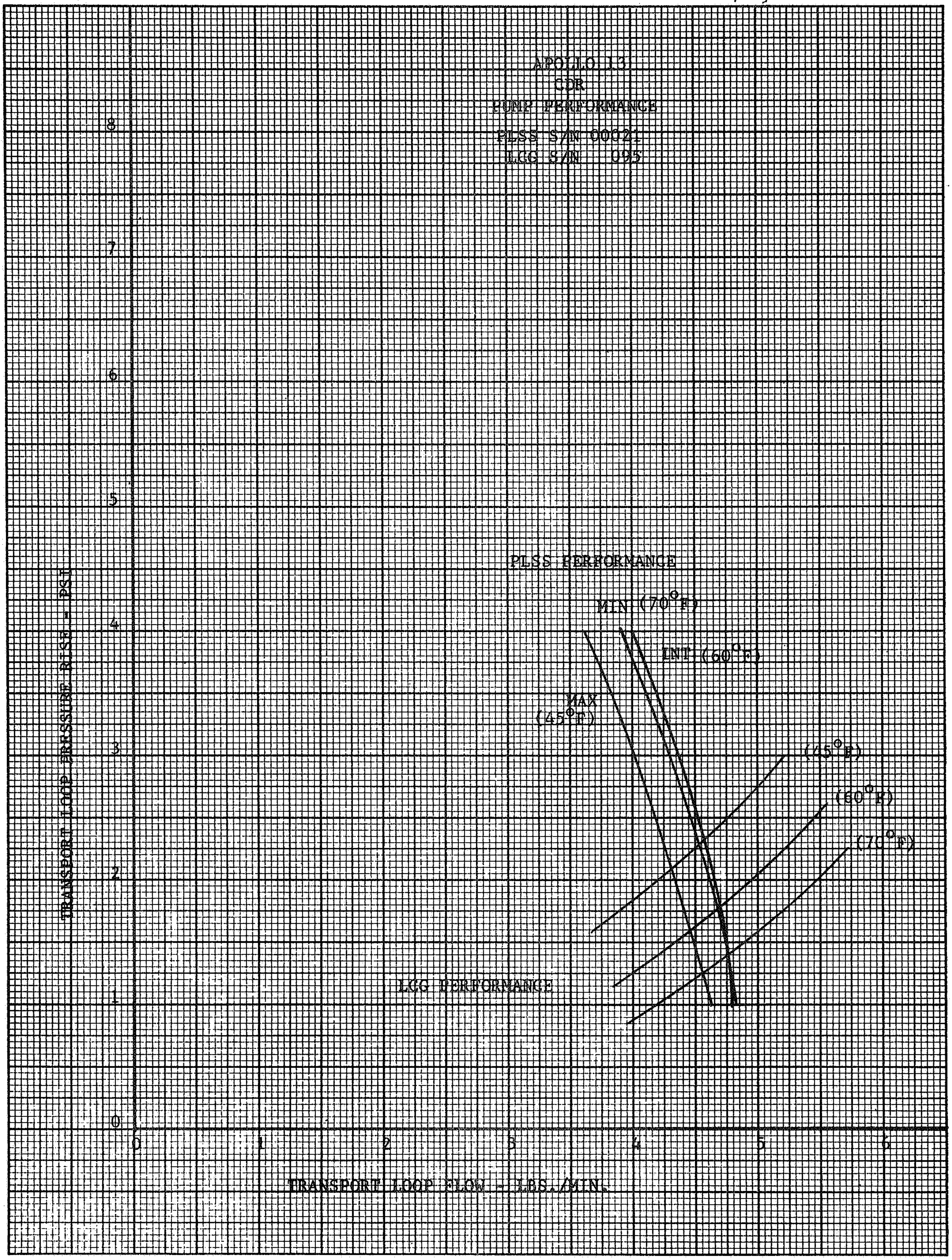
Amendment 30
4/13/70

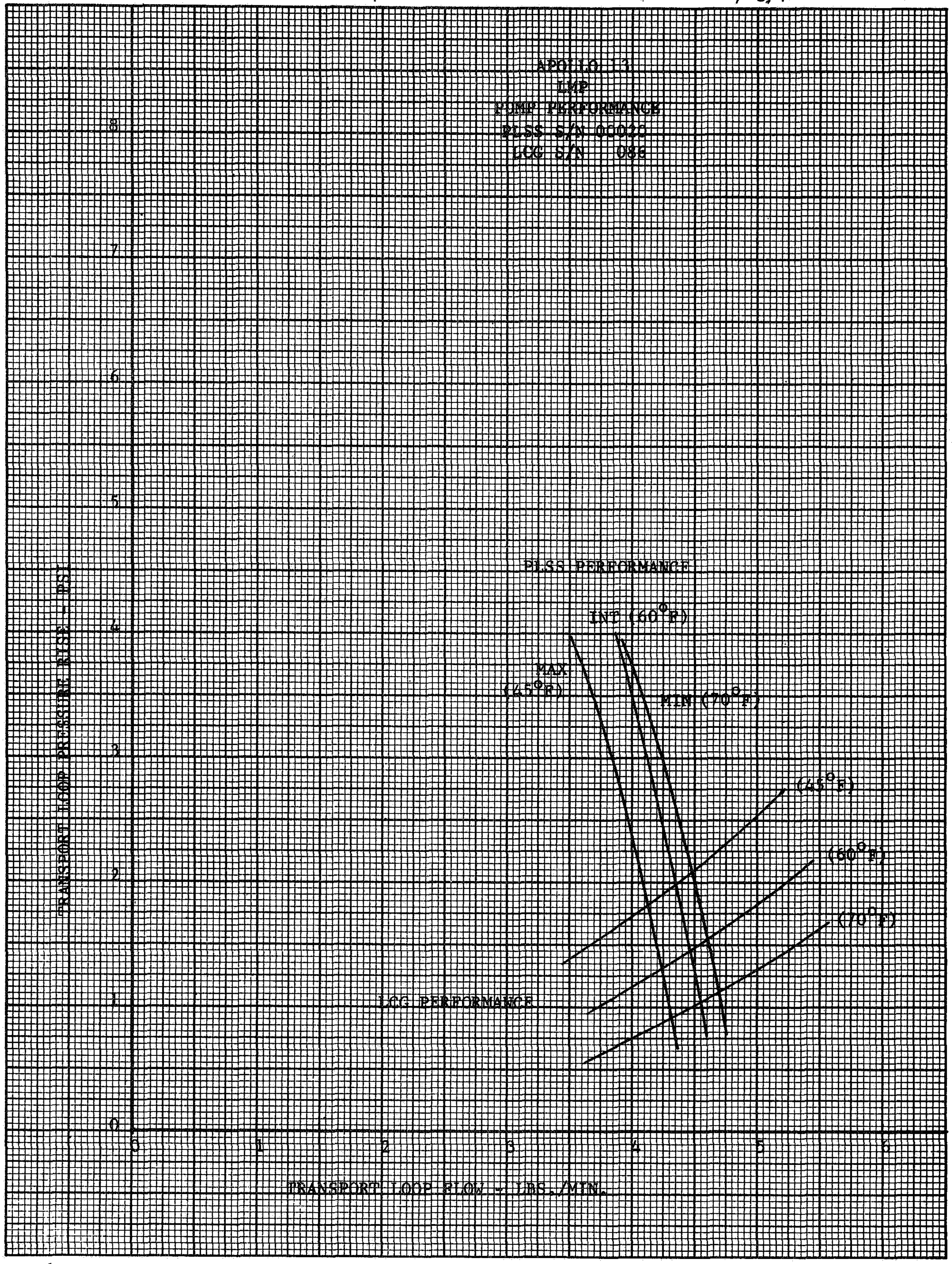


Amendment 30
4/13/70

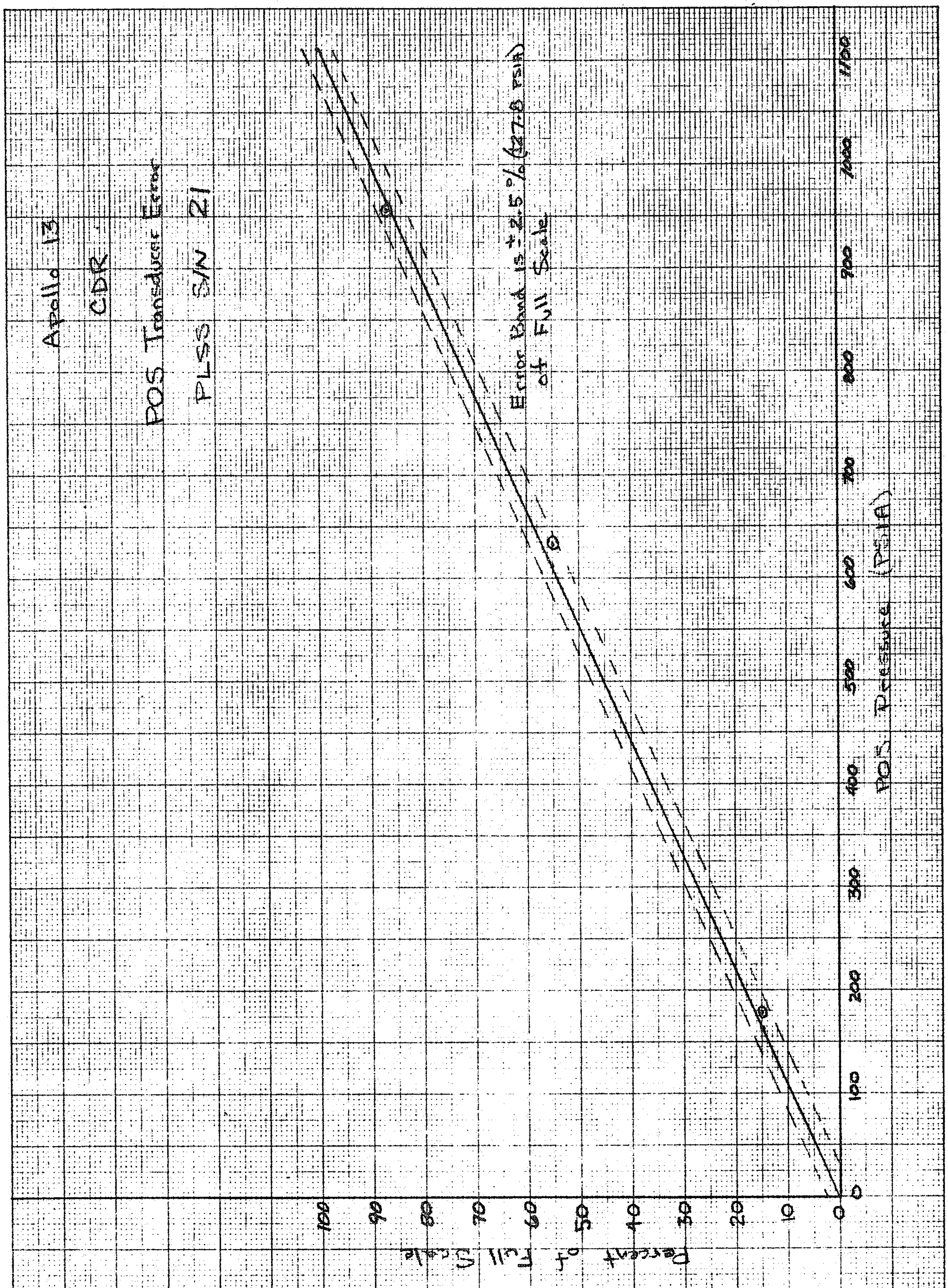


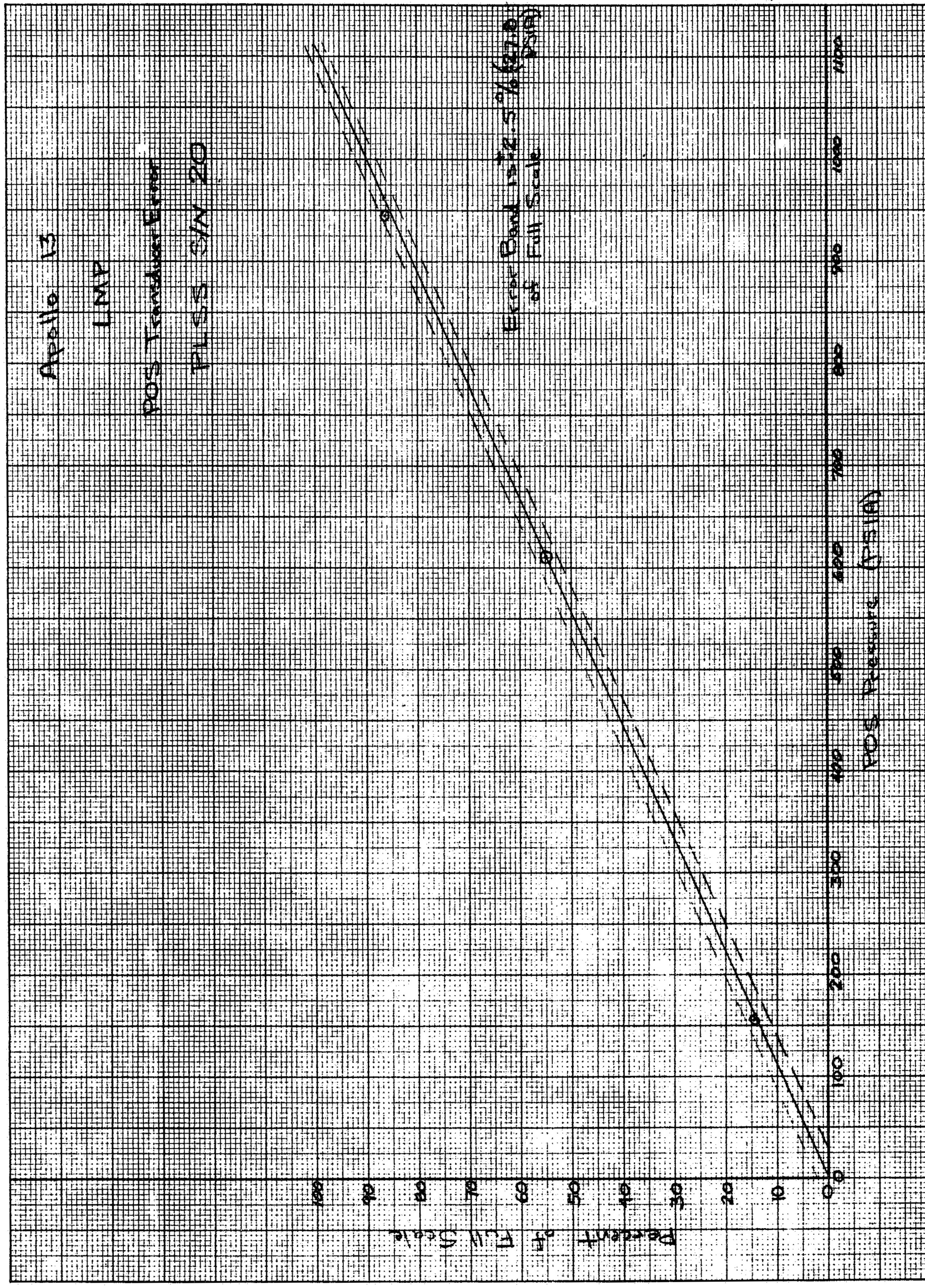

APOLLO 13
LMP
FAN PERFORMANCE
PLSS S/N 00020
PGA S/N 061
PLSS PTA Performance
Predicted PLSS EVA Performance
Haise PGA Characteristics
PLSS PRESSURE RISE - INCHES H_2O
O_2 FLOW - ACFM
0
1
2
3
4
5
6
7
8
5.5


APOLLO 13
CDR
PUMP PERFORMANCE
PLSS S/N 00021
LCG S/N 095
PLSS PERFORMANCE
MIN (70°F)
INT (60°F)
MAX (45°F)
(45°F)
(60°F)
(70°F)
LCG PERFORMANCE
TRANSPORT LOOP PRESSURE RISE - PSI
TRANSPORT LOOP FLOW - LBS./MIN.
0
1
2
3
4
5
6
7
8

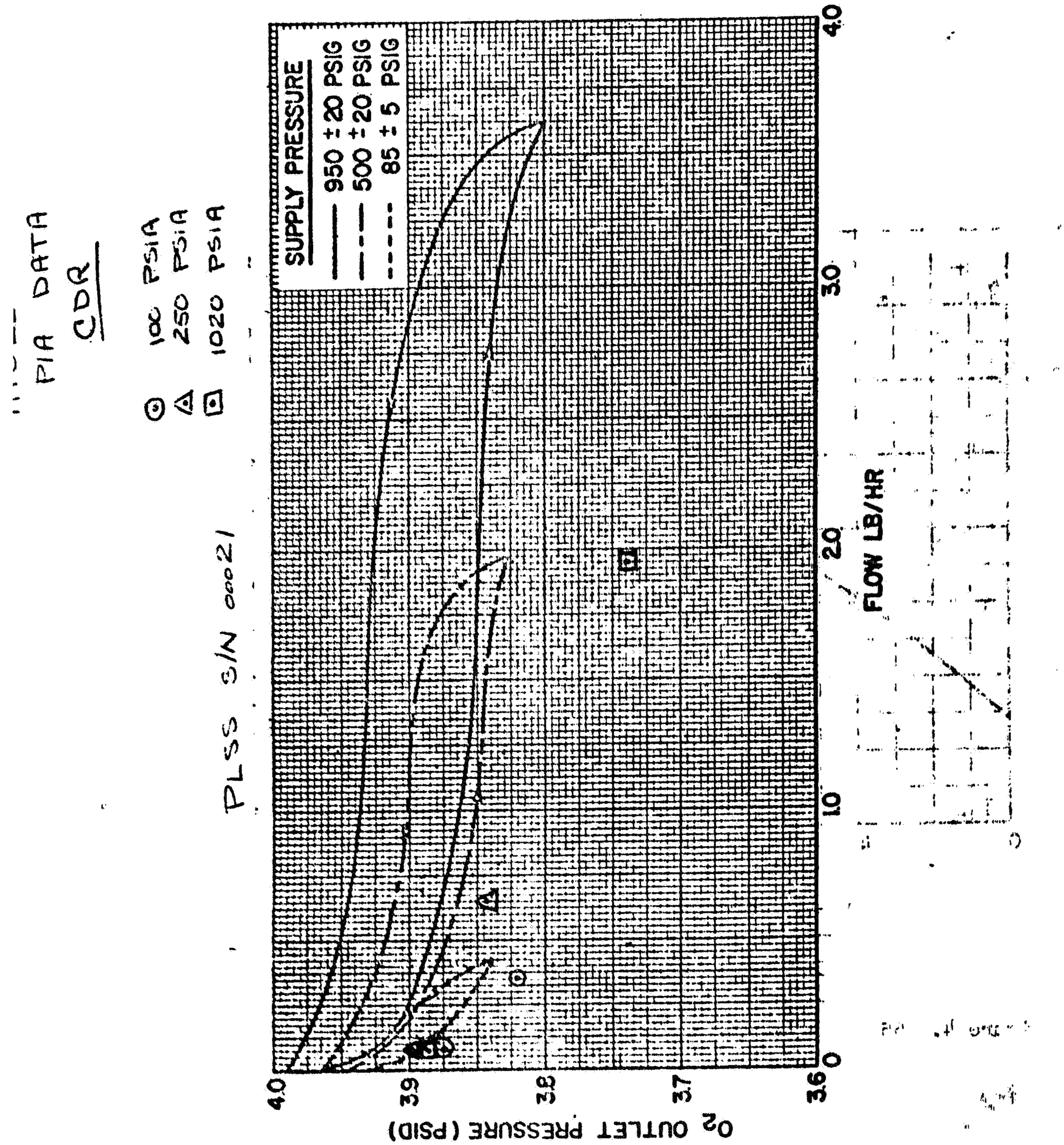


K+E 10 X 10 TO ½ INCH 46 1473
7½ X 10 INCHES MADE IN U.S.A.
KEUFFEL & ESSER CO.

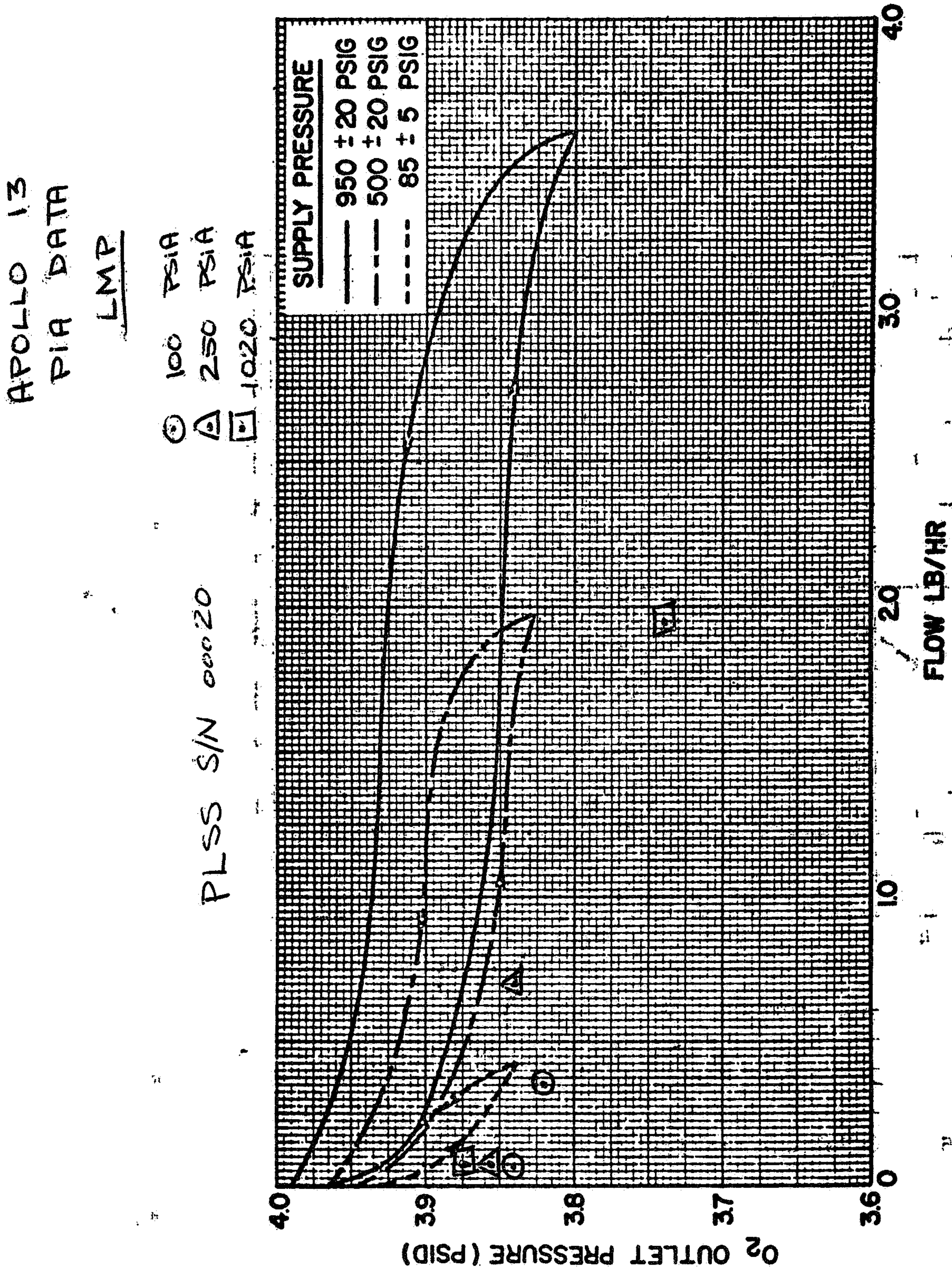

Apollo 13
CDR
POS Transducer Error
PLSS S/N 21
Error Band is ±2.5% (±27.8 PSIA)
of Full Scale
0
100
200
300
400
500
600
700
800
900
1000
1100
POS Pressure (PSIA)
0
10
20
30
40
50
60
70
80
90
100
Percent of Full Scale


Apollo 13
LMP
POS Transducer Error
PLSS S/N 20
Error Band is ±2.5% of Full Scale (±27.0 psia)
POS Pressure (PSIA)
Percent of Full Scale
0
100
200
300
400
500
600
700
800
900
1000
1100
10
20
30
40
50
60
70
80
90
100

Amendment 30
4/13/70



Primary O_2 Regulator Performance



Primary O_2 Regulator Performance

		PERFORMANCE SPEC.	CDR.	LMP.
OPS				
-S/N			015	030
-Leakage				
Low Pressure External				
At 4.25 PSID	(SCC/Min)	.05 CC/Sec.	.0000192 CC/Sec.	.00478 CC/Sec.
High Pressure External				
At 6935 ± 200 PSIG	(SCC/Hr)	.0056 CC/Sec.	.0009696 CC/Sec.	.000378 CC/Sec.
Internal Leakage				
Across Regulator	(SCC/Min)	200 SCC/Min	0.0 SCC/Min	60 SCC/Min
-Purge Flow Characteristics				
Flow Rate	(Lbs/Hr)	8.3±1 Lb/Hr.	8.3 Lb/Hr	8.3 Lb/Hr
Bottle Pressure-Start	(PSIA)	485 Min in 30 Mins	6700 PSIG	6200 PSIG
-Stop	(PSIA)		1500 PSIG	1400 PSIG
Regulated Pressure - Maximum	(PSID)	3.70 ±0.3	3.68 PSID	3.65 PSID
-Minimum	(PSID)		3.52 PSID	3.50 PSID
-Make-up Flow Characteristics				
Flow Rate	(Lbs/Hr)	.08-.14 Lb/Hr	.08-.14	.08-.14
Bottle Pressure	(PSIA)	--	6750 PSIG	6750 PSIG
Regulated Pressure -Maximum	(PSID)	3.70 ± 0.3	3.825-	3.91-
-Minimum	(PSID)		3.65	3.79
OPS Checkout Orifice				
Flow at 818 PSIA	(Lbs/Hr)	0.3 Lb/Hr Max	.215	.220

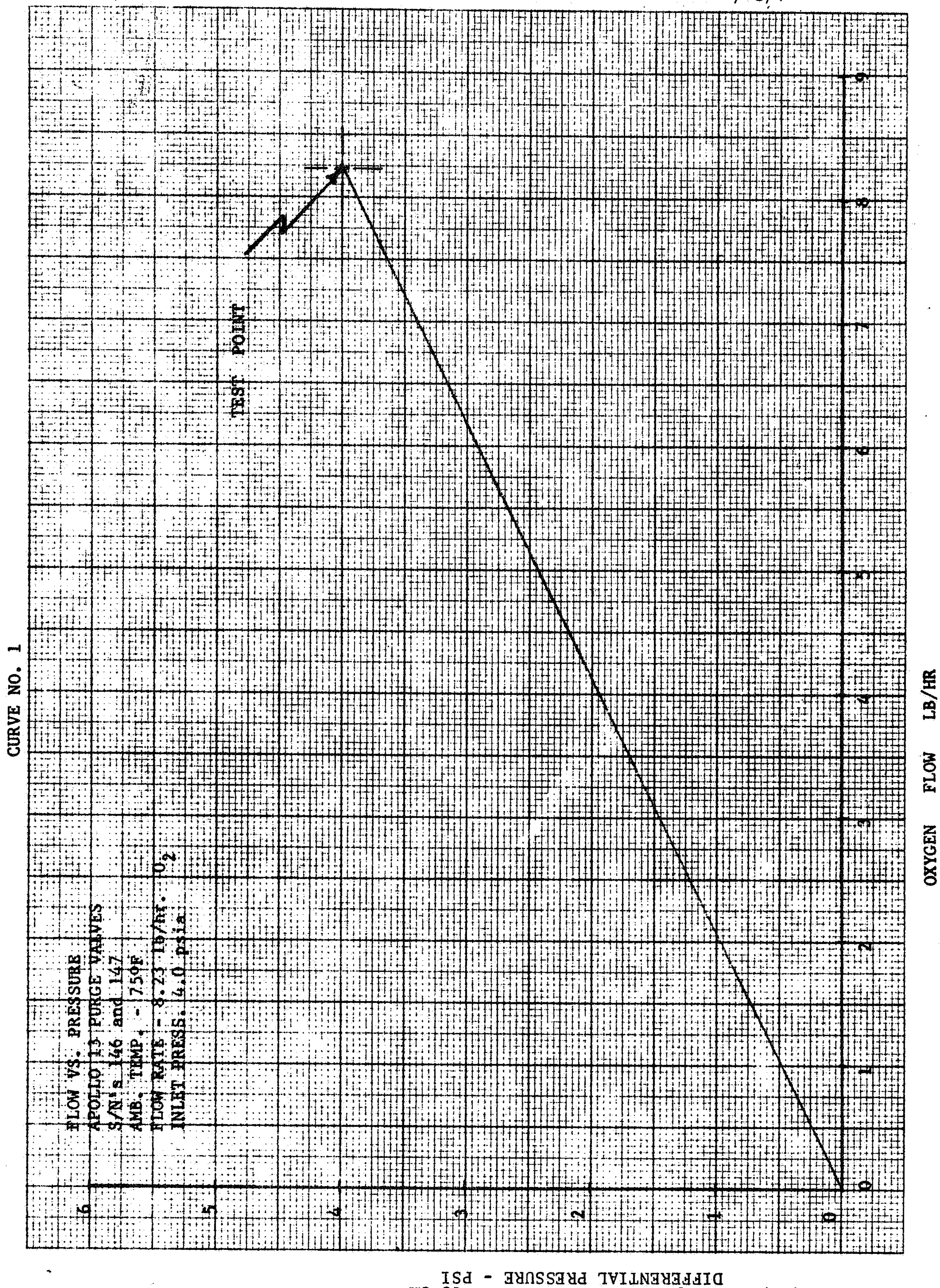
	SPEC.	CDR.	LMP.
OPS, (Cont'd)			
-OPS Checkout Gage - Actual			
Pressure when gage reads:			
1) 3.5 PSID	±0.10	3.43	3.49
2) 3.8 PSID	±0.10	3.82	3.79
OPS Quantity Gage	±300	Actual Press 6750	Actual Press 6750
		OPS read 7000	OPS read 6800

OPS Purge Mode Duration

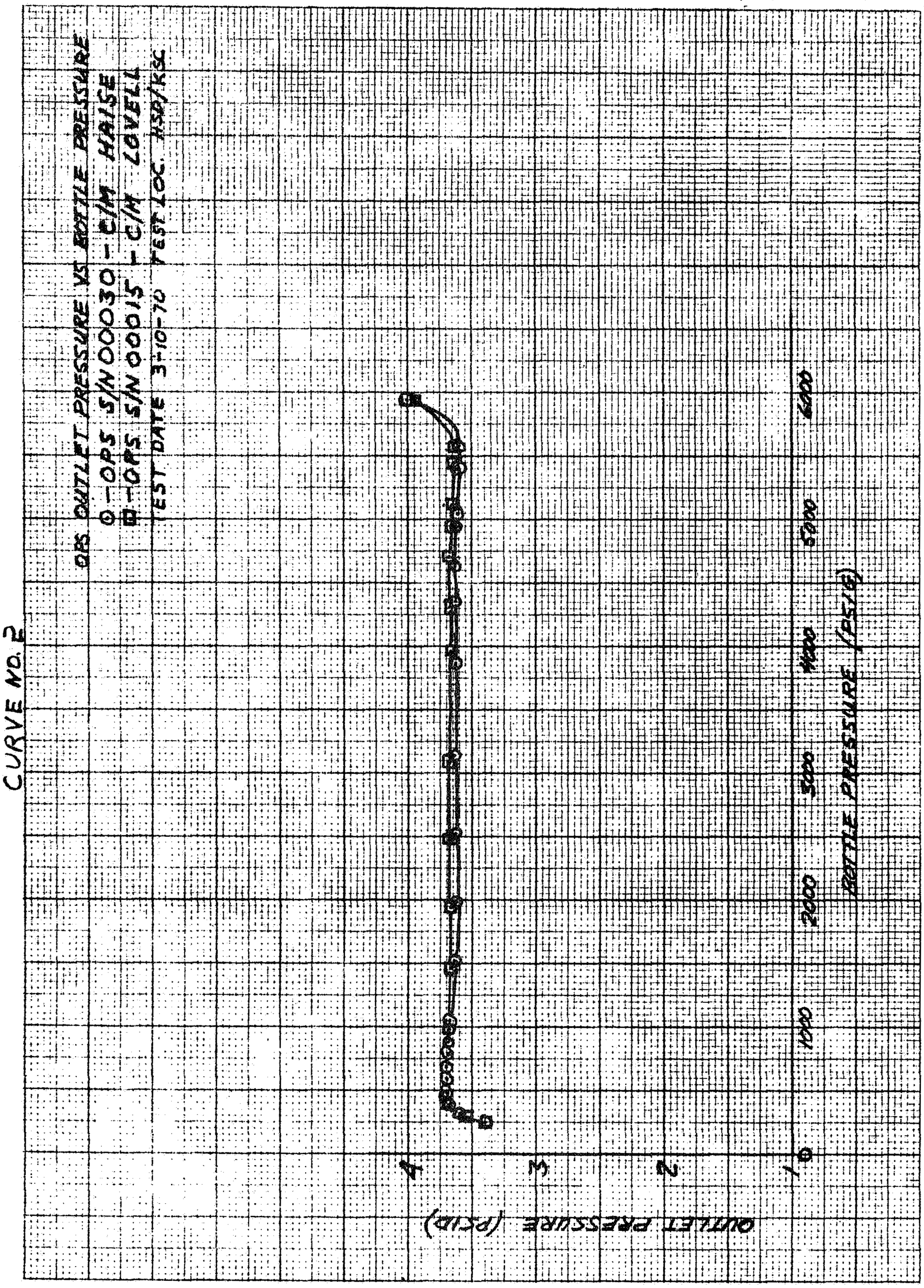
The data presented below, and in the curves which are referenced, are not meant for planning purposes but represent as precisely as possible the actual hardware characteristics of the Apollo 13 prime equipment. The data does not reflect any mission constraints or operating red lines.

Curve No. 1 - Purge Valve Flow vs. "Suit Pressure"
Curve No. 2 - OPS Outlet Pressure vs. Bottle Pressure
Curve No. 3 - OPS Bottle Pressure vs. Time

TO DETERMINE DURATION	PGA S/N 078 OPS S/N 00015	PGA S/N 061 OPS S/N 00030
A. Avg. OPS Outlet Press. (Curve #2)	3.67 psia	3.63 psia
B. Press. Drop Across Suit (OPS to Purge Valve)	.033 psi	.031 psi
C. Avg. "Suit Pressure" (A-B)	3.64 psia	3.60 psia
D. Actual Purge Flow (Curve #1)	7.50 lbs/hr	7.42 lbs/hr
E. Duration in Purge Mode (Inverse Ratio from Curve #3)	45.78 minutes	46.31 minutes

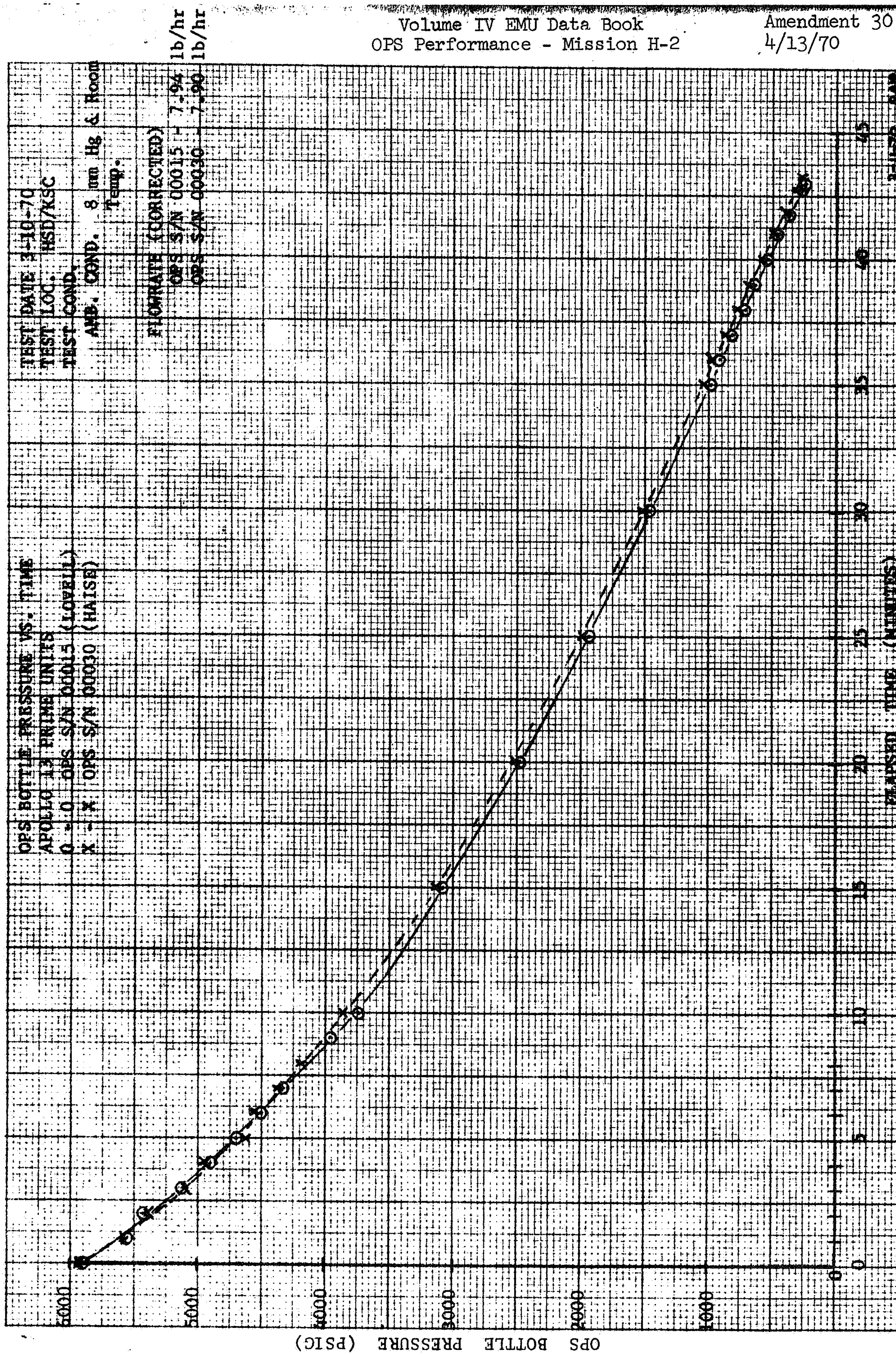


BASE 20x20 TO INCH


CURVE NO. 2
OPS OUTLET PRESSURE VS BOTTLE PRESSURE
O - OPS S/N 00030 - C/M HAISE
□ - OPS S/N 00015 - C/M LOVELL
TEST DATE 3-10-70 TEST LOC. HSD/KSC
BOTTLE PRESSURE (PSIG)
0
1000
2000
3000
4000
5000
6000
OUTLET PRESSURE (PSID)
1
2
3
4

BEE 20X20 TO INCH

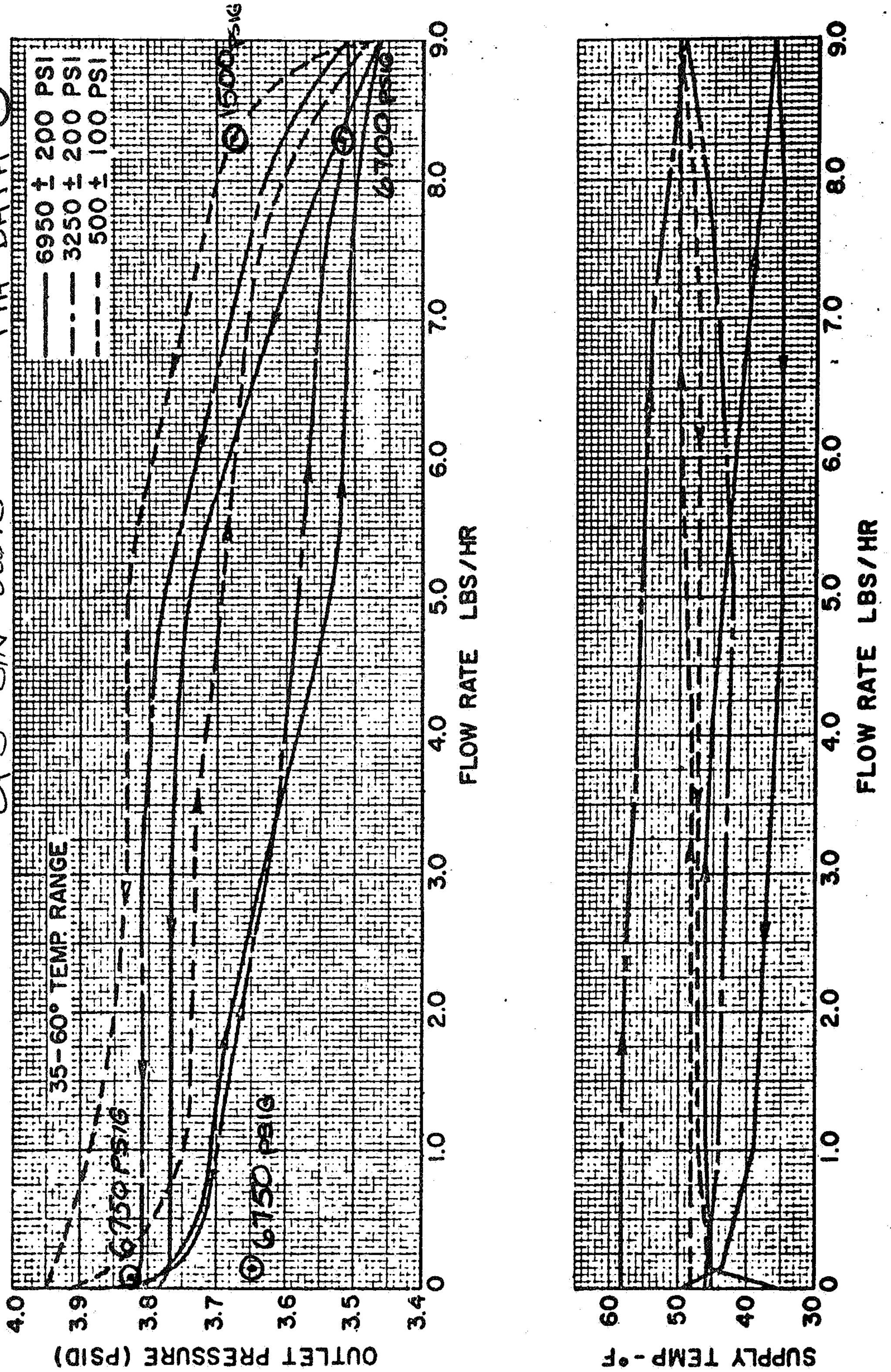
CURVE NO. 3



APOLLO 13

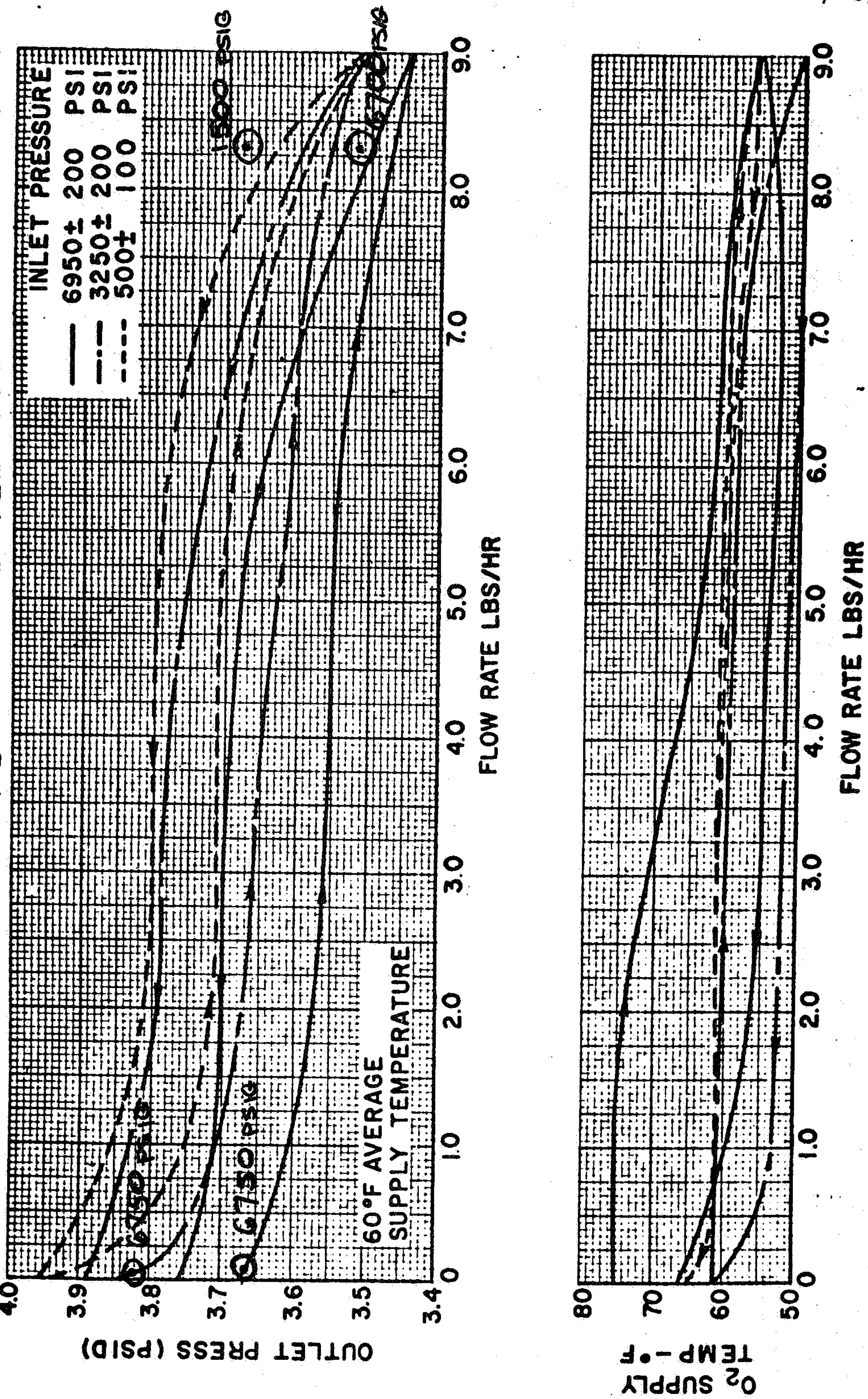
CDR
PIA DATA

OPS S/N 0015



OPS O_2 Supply Temperature and Outlet Pressure Versus Flow (35 - 60° Temperature Range)

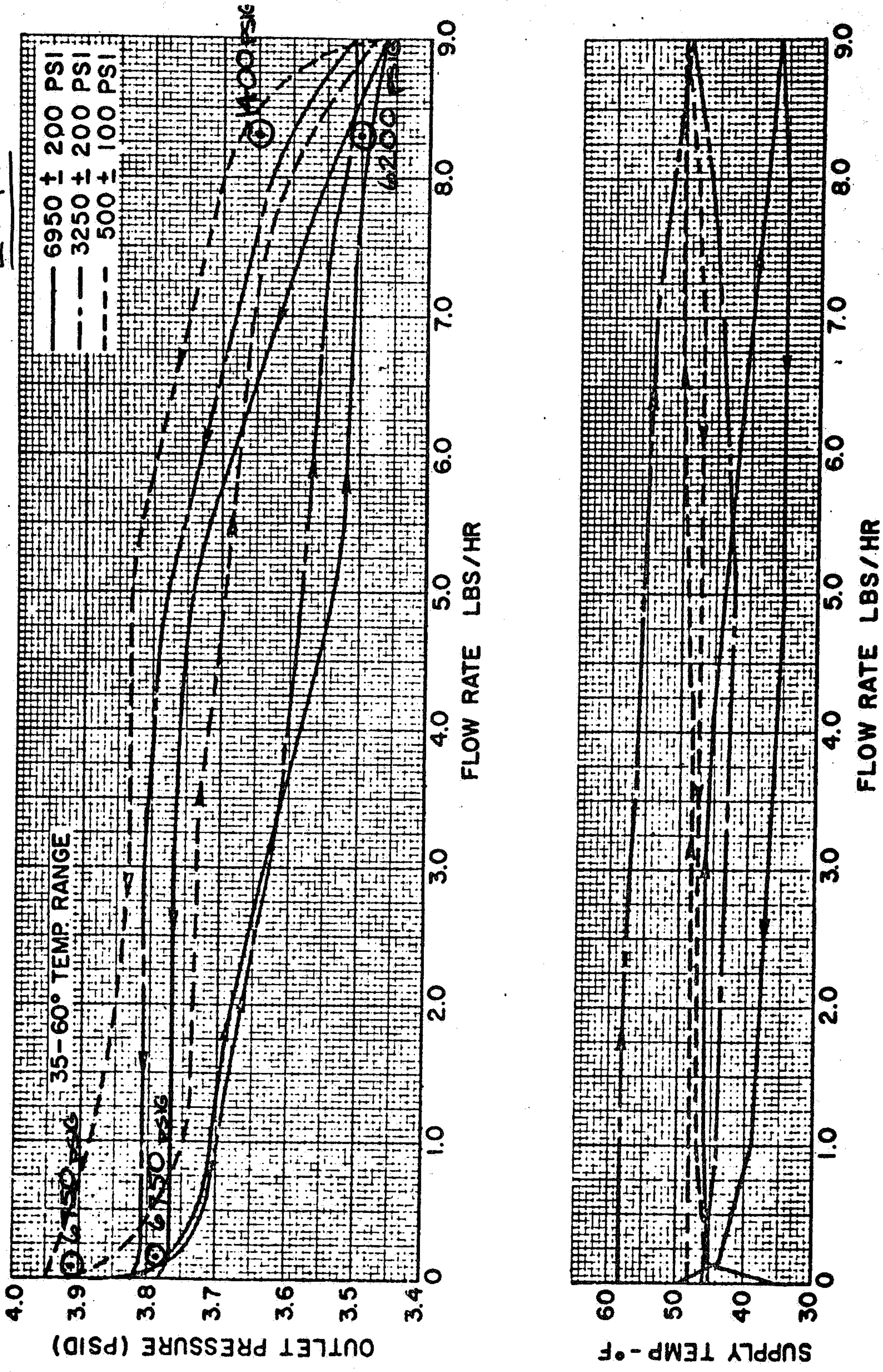
APOLLO 13
CDR
OPS S/N 0015 — PIA DATA



OPS O_2 Supply Temperature and Outlet Pressure Versus Flow (60° Average Supply Temperature)

APOLLO 13 PIA DATA ⊙
LMP

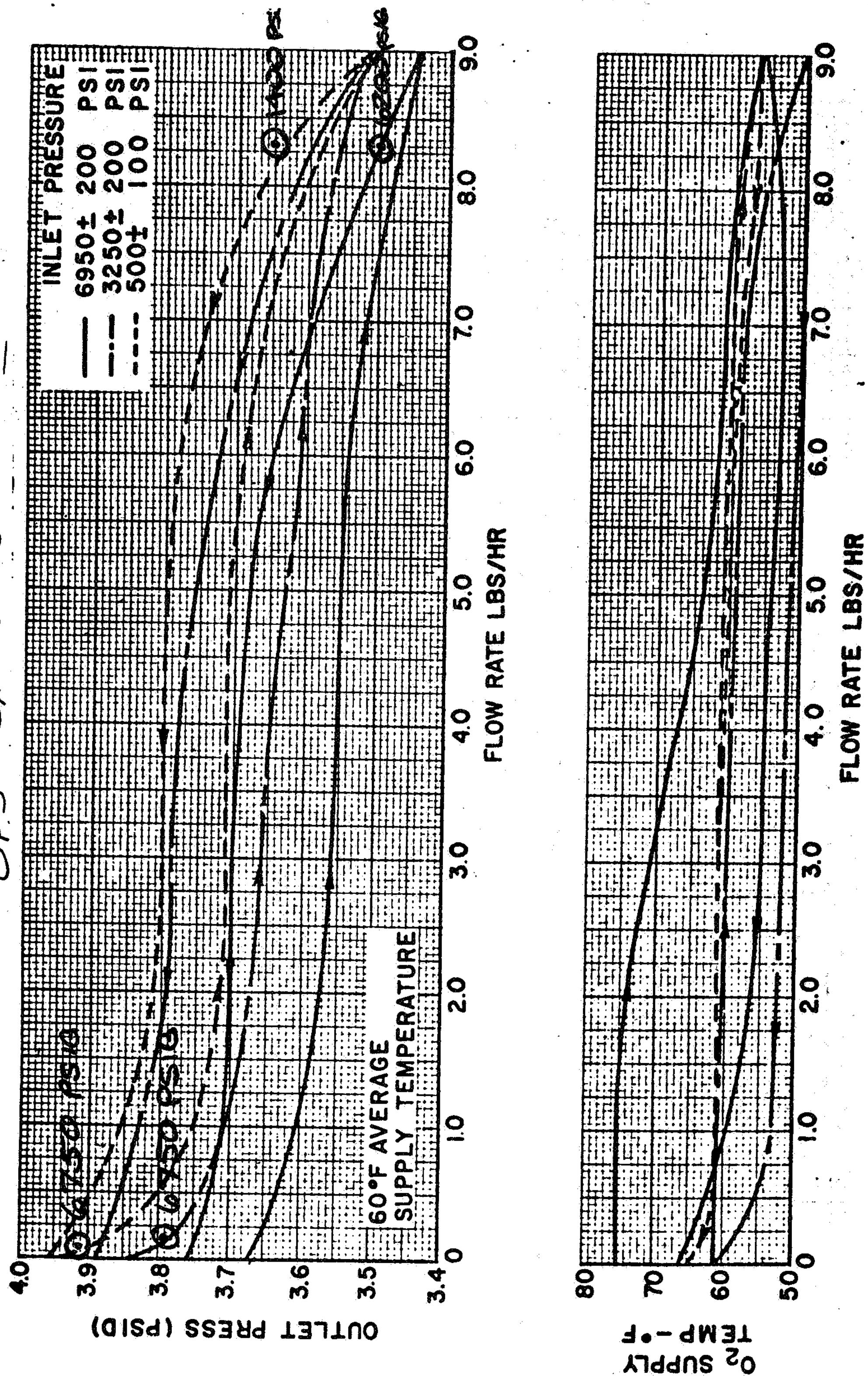
OPS S/N 000 30



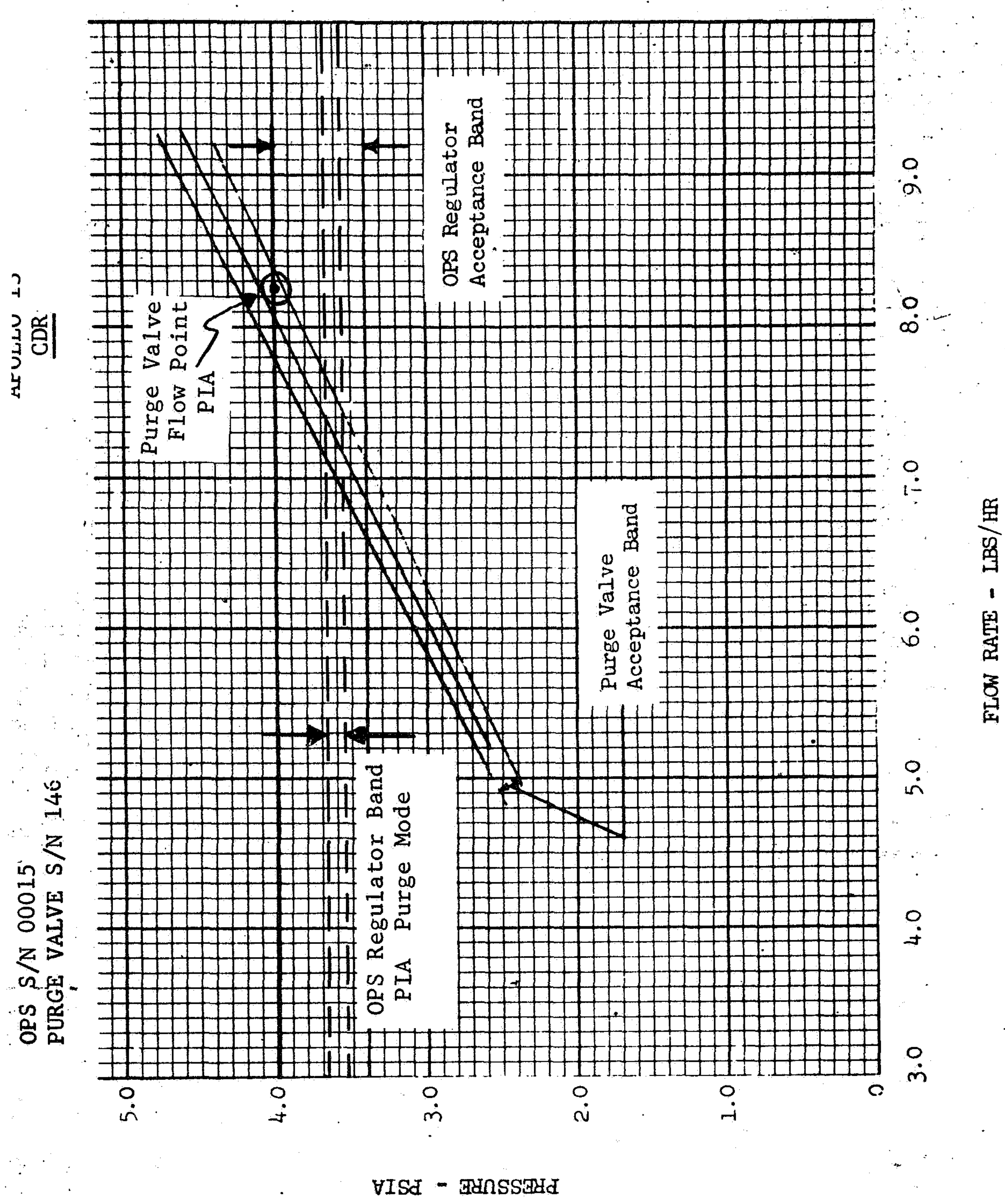
OPS O_2 Supply Temperature and Outlet Pressure Versus Flow (35 - 60° Temperature Range)

APOLLO 13
PIA DATA
LMP

OPS S/N 000 30

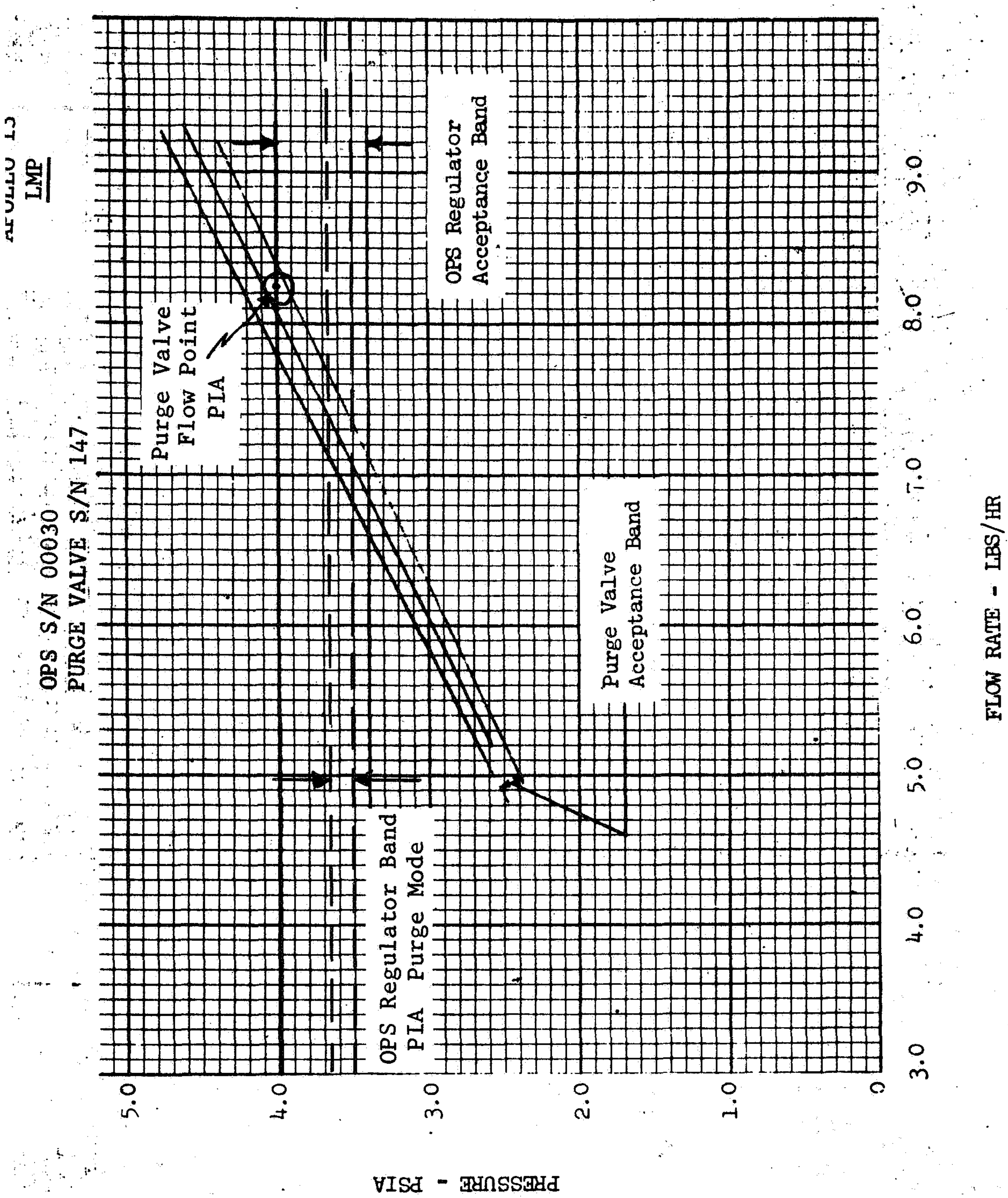


OPS O_2 Supply Temperature and Outlet Pressure Versus Flow (60° Average Supply Temperature)



OPS FLOW RATE VERSUS PRESSURE AS DICTATED BY
PURGE VALVE

Amendment 30
4/13/70



OPS FLOW RATE VERSUS PRESSURE AS DICTATED BY PURGE VALVE

PERFORMANCE

	SPEC	CDR	LMP	CMP
PGA				
S/N		078	061	088
Leakage (SCC/MIN)				
@3.75 psid	180scc/min	80	60	130
Pressure Drop (in. H_2O)		73°F	74.3°F	
EV @ 6.0 scfm 18.6 ± .1 psia AIR	5.13 max in H_2O (spec equivalent)	L.H. 3.0	L.H. 2.45	
IV @ 12.0 scfm 18.2 ± .1 psia	15.1 max in H_2O (spec equivalent)	L.H. 6.3 R.H. 6.4	L.H. 6.15 R.H. 6.6	
O_2 - IV @ 12.0 scfm 18.2 ± .1 psia	16.2 max in H_2O (spec equivalent)	7.8	8.7	8.4
Relief Valve				
Flow Rate (scfm @ 5.5 psig suit pressure		4.2	5.5	
Cracking Pressure (psid)	5.5 psi max	4.93	5.10	
Reseat Pressure (psid)	4.8 psi min	4.85	4.95	
PGA Cuff Gage Accuracy				
Actual Pressure when cuff gage reads:	± 0.15 psi			
1) 3.0 psid		3.04	3.0	3.04
2) 3.5 psid		3.52	3.52	3.53
3) 4.0 psid		4.02	4.02	4.05
4) 4.5 psid		4.55	4.5	4.52
5) 5.0 psid 5.5 psid		5.02 5.53	5.0 5.52	5.0 5.52
6) 6.0 psid		6.0	6.0	6.03

PERFORMANCE

	SPEC	CDR	LMP	CMP
LCG				
S/N		095	086	
Pressure Drop @ 19.0 psig inlet				
At least six points of flow vs. pressure drop				
1) (Lbs/Min) 3.0		1.3	1.3	
2) 3.5		1.8	1.6	
3) 3.8		2.0	1.8	
4) 4.0		2.1	2.0	
5) 4.3		2.4	2.3	
6) 4.5		2.6	2.4	
7) 4.8		2.9	2.8	
8) 5.0		3.1	2.9	

	SPEC	CDR	LMP	CMP
Purge Valve				
S/N		146	147	
Flow Rate @ 4.0 ± 0.05 psia (lb/Hr.)	8.1 ± 0.3 lbs_m/Hr at 90°F O_2 and 4.0 ± .05 psia	8.0 lbs_m/Hr	8.0 lbs_m/Hr	
Leakage @ 3.85 ± 0.15 (Valve Closed) (SCC/MIN)	4 scc/min	4	4	

Apollo 13 Heat Leaks

The nominal heat leak for Apollo 13 EVA#1 is minus 75 Btu/hr.

The nominal heat leak for Apollo 13 EVA#2 is minus 10 Btu/hr.

The worst case heat leak for both EVA's is plus 280 Btu/hr.
(Considering operation in some of the more severe craters in the landing site.)

APOLLO 13

STEADY STATE ENVIRONMENTAL HEAT LEAK* (BTU/HR)

LCG INLET TEMPERATURE	EVA 1 ENVIRONMENT			EVA 2 ENVIRONMENT			
	MESA 12° SUN 1	LUNAR PLANE 15° SUN 1	LUNAR PLANE 15° SUN 2	LUNAR PLANE 25° SUN 1	LUNAR PLANE 25° SUN 2	4:1 CRATER 25° SUN 1	4:1 CRATER 25° SUN 2
78-80°F	-38	-30	-13	-8	15	130	155
57-60°F	-30	-25	- 5	0	20	135	160

* Crewman metabolic rate assumed = 1000 Btu/hr.

1 - Clean ITMG

2 - "Dirty" ITMG - thermal properties degraded to Apollo 12 conditions